Failure Analysis 101

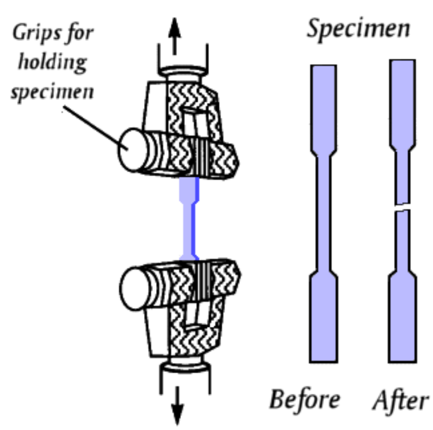
Forensic or failure analysis is a fine art with a whole industry and scientific community associated. Yet, some principles readily extend to any failure you may come across. This limited knowledge may help in learning the cause of part failure in irrigation systems.

The primary purpose of finding the source of failure is to prevent continuing or future problems. As an analyst, it is important to enter any examination with a open mind, not biased with a preconceived conclusion. As commonly repeated on the popular TV crime investigation shows, "see where the evidence leads"! Although all the examples and principles we will talk about focus on PVC piping systems, most correlate to other materials.

The first and most important step in resolving the cause is to understand the circumstances that affected the part and possibly led to its failure. Answers to questions such as the position and role within the system, time of day, cycle phase, system pressure, and ambient weather may provide important information to finding the root of the failure. These questions are even more important when looking into a series of similar failures. Even with a single or isolated incident, assume it may be the first of more to come and the information collected can help pinpoint the true cause. Obvious randomness disappears and a pattern develops when information gathers from multiple failures is brought together.

When analyzing a failure the more extensive the collection of exemplars or fragments the easier it is to pinpoint the source, or cause. Cleaning of the residual mud or dirt is essential once the collection is centralized. Care is critical, to not destroy a telltale sign of the origin. Generally, for plastics, a gentle stream of water will work; do not use brushes, scrub pads or anything that will destroy any of the surfaces or indicators.

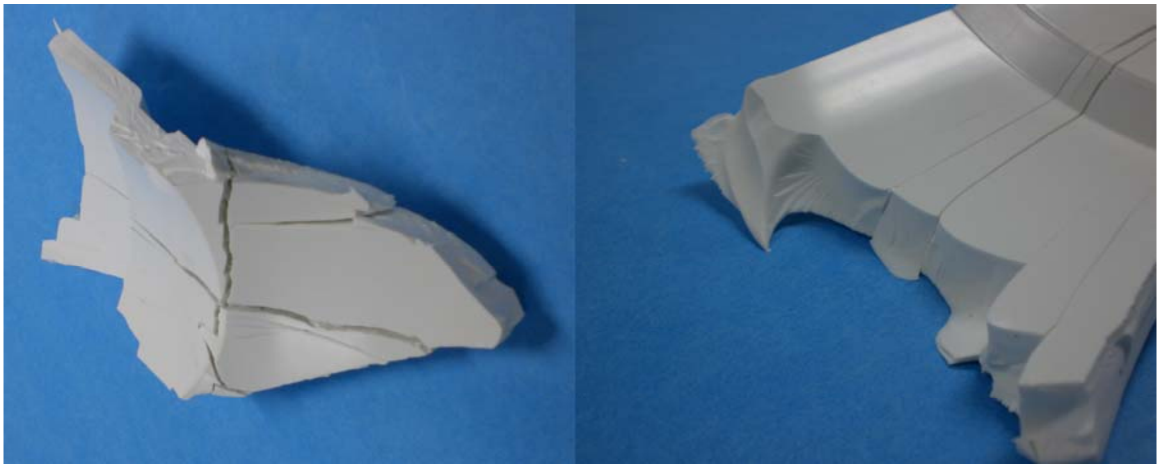
First, it is important to realize that the orientation of fractures, cracks and breaks are perpendicular to the direction of the causing forces. For example, we can use a paper strip to show the mechanics principle of a failure. When pulled at both ends, a long rectangular strip will tear in a direction that is perpendicular or at right angle to the direction of the applied loads.



This is similar to the standard tensile test, where a sample is pulled lengthwise until it breaks across the midsection. The point here is, the orientation of the crack, or tears, will tell the direction the damaging loads where applied. To sum up, when going over piping components the orientation of the failure mode can help to categorize the cause as either hydraulic, internal pressure, or external loads such as bending, vibration or impact.

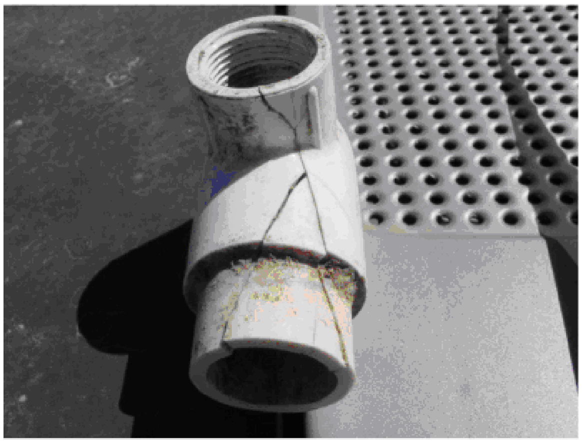
If the failure or crack is around the circumference of a pipe or fitting the cause was due to external forces, such as bending or vibration. A crack that parallels the waterway is the result of internal or hydraulic loading. Excessive internal pressure, in the form of hoop stress, which attempts to enlarge diameter of the pipe or fitting will produce a tensile failure or crack parallel to the waterway. Threaded fittings that split are evidence of exposure to internal loads, from the tapered pipe threads, and not usually from system pressure. The taper of the male and female components wedged together during tightening attempts to stretch the female part to a larger diameter. As the diameter increases the wall is stretched and a longitudinal crack is the outcome.

The texture of the failure surface shows a lot about its progression. Sharp, jagged edges are a strong sign of rapid failure mode. Brittle material or failures from extreme pressure are most common reflected with these almost razor sharp fragments.



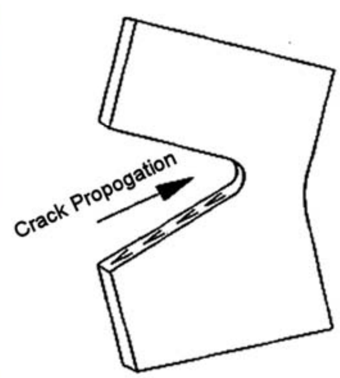
Examples like this are usually found after a burst pressure test! When the system is pressure tested and completely filled with water, the sharp and dangerous fragments will be contained within a few yards. Yet, if the system had been leak tested with air, or it had an air pocket, then a failure can propel these shrapnel pieces hundreds of feet with potential for serious injury for anyone nearby.

When PVC piping fails from water freezing internally the natural phenomena of cold embrittlment has played a major role in the failure surface. Buried piping systems will not have the above results except freeze breaks. Breaks due to frozen water have the similar sharp edges.



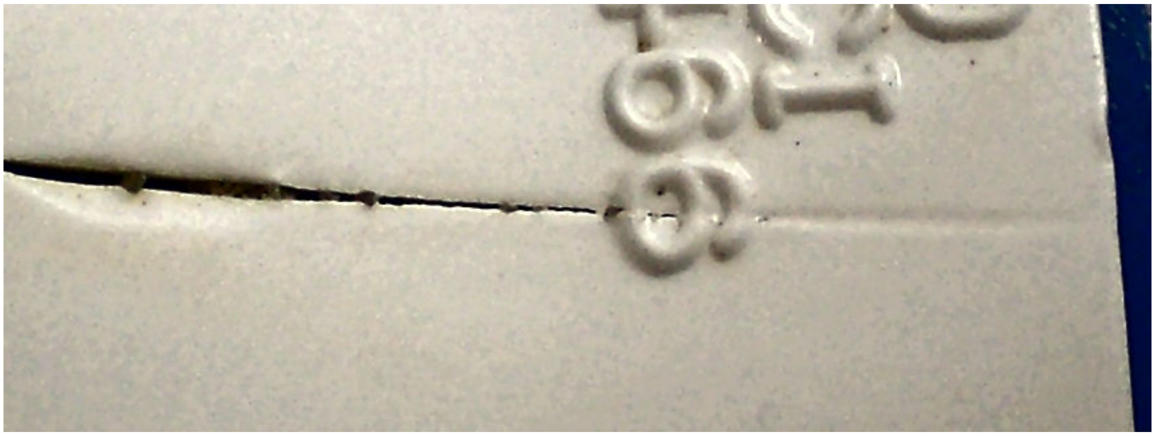
Notice that the fracture lines are straight and take the form of either a “V” or “Y”. Pieces are not scattered, but rest close to the source.

The fracture surface that results from a slow progression has a defined pattern often labeled as “beach marks.” The ridges and valleys of the fracture surface also point toward the failure origin. This mode is generally the consequence of a failure that progress’ over a “long term” and multiple incidents of the cause. Still, in the vernacular of failure analysis, “long term” can be short in the span of time, maybe even a fraction of a second. Besides, many times the failure time line will consist of beach marks at the beginning, and end with a catastrophic result.



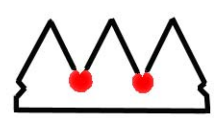
Because plastics, and specifically PVC, are pliable, a failure that is the result of long-term stress shows various amounts of creep. Creep is the tendency of a solid material to deform permanently under the persuasion of loads. It occurs because of continuing exposure to levels of stress that are below the failure strength of the material. The appearance of a failure that is the result of many pressure cycles over a long time will have beach marks on the fracture surface.

Directional fittings are the most common examples of creep failure, near the interior of a “direction change” often called the crotch. PVC is a visco-elastic material and reacts to tensile loads more closely related to taffy than to glass. Slow, medium loads will cause the material to stretch. But, a sharply applied load will cause the material to snap. A failure from multiple surge cycles will have “stretch marks” at the end of any surface crack. Many times these indicators can foretell system leaks.



There are two types of threaded connections failures, either male or female. When tightening tapered pipe threads, the sealing of the joint happens when the male is wedged into the female part. This compresses the diameter of the male part, and stretches the female diameter. Compressive loads are not harmful, but the stretching loads quickly cause a crack. The crack begins along the thread engagement diameter, and progresses outward. Once the crack starts, wall thickness of the female part offers little resistance or added protection.

Notice that both the reducer bushing and the assembled coupling are cracked. Once started, the crack progressed through the double wall where a coupling had been solvent welded. The extra materials of the two walls afford little if any added protection. A common misconception is that using Schedule 80 threaded fittings will prevent this failure. The only solution is to use proper installation procedures and not to over tighten the joint.



Stress risers

The taper of a male thread removes some pipe wall in the threaded segment. This and the inherent stress riser at the root, or bottom of the thread, is structurally the weak link of a joint. The localized stresses, which are, actualized at the valley of the "V" cuts the strength of the threaded section substantially.

This drop in structural strength becomes the potential for failure at the point of the first exposed male thread, outside of the female.

Any external bending or vibration on this connection will soon end with the male threaded part failing at the root of its first exposed thread. This is structurally weakest link of the joint!

Not all attempts at failure analysis can provide the precise cause. Yet, when looking into a system or part failure it is important to collect as much information, debris, operation parameters' and even photos to helping finding the cause. A comprehensive investigation can remove many alleged or suspect causes, helping to focus on the true origin.

It is also important to share the situation with the manufacturer of the products involved. The knowledge of their product, its strengths, limitations, uses, and history may prove as an invaluable key to your investigation and conclusion.

Larry Workman
Expert4PVC Consulting
www.expert4pvc.com