

Failures to Communicate: Part 1 DRAFT WRITTEN FOR the JOURNAL OF FAILURE ANALYSIS AND PREVENTION **COPYRIGHT ASM INTERNATIONAL**  
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There should be no doubt that the root cause of many failures can be found in a breakdown of communication. Avoidance of failure requires information transfer and coordination among various disciplines in the design stage, embodiment of the design via manufacturing, and sufficiently detailed and clear operating, maintenance, and inspections instructions to allow for a lifetime of successful service. Experienced failure analysts can certainly provide many examples in which the underlying cause of a failure was communication related. The editors intend this article to be the first of a series highlighting such organization or system related failures. The first few articles will be specifically related to communication failures.

Most failure analysts who come from a materials engineering background are approached by fellow engineers or others who

**"Well what we got here is a failure to communicate."**

**Paul Newman, Cool Hand Luke, 1967.**

wish to have our help in resolving a "failure" issue. Often, the one requesting the investigation wants to know if "the part had a defect." Often, the alternative, in their mind, is that the "product was abused." The authors would like to encourage all involved in failure analysis to go beyond this somewhat oversimplified type of investigation, where there are only two possible causes of failure. In order to facilitate this, we would like to begin our series on communication related failures with the word "defect." Using the word "defect" without careful attention to the possible interpretations that different people might make can lead to communication problems during design, manufacturing, service or post service failure analysis. However, it is usually during the failure analysis that the other communication failures are discovered.

To start off our discussion, let's think about the ways the results of an engineering failure analysis are communicated to people with and without technical backgrounds. Open minded failure analysts generally acquire a rather broad ranging knowledge base, a consequence of willingness to delve into our works and produce something useful to those outside our own fields, be that mechanical, manufacturing or quality engineers, the users of the subject component or assembly, or attorneys handling a litigation matter. Failure analysts from materials backgrounds might want to consider reminding the others involved in the situation that they will not get the best information from the investigation if they are confined to determining whether or not "There was a defect."

Failures to Communicate - What's in a Word?

What is a “defect?” The new ASM Handbook Volume 11, Failure Analysis and Prevention, includes a discussion of this term. It was, to say the least, somewhat controversial. In the end, the definition included in the Handbook represented the consensus of a small group of people, in this case, the authors of this article. But what is really important is what is meant by those who use the term and what is understood by those who hear the term.

For example, materials engineering education usually goes into some detail describing the ways in which real materials deviate from an ideal. Tow of the authors studied from the second edition of Reed-Hill’s classic Physical Metallurgy Principles, which includes the following state in section 4.2:

”The explanation for the discrepancy between the computed and real yield stress lies in the fact that real crystals are not perfect, but contain defects. Experimental proof for the existence of these defects can be obtained with the aid of the electron microscope.”

As another example, if one examines the origin o fa fracture at high enough magnification, it is not surprising to find some imperfection which is responsible for the fracture initiating where it did verus, say, another location 0.002 inches away. Some analysts will say, and even write, “Here is the ..... scratch, the pore, the microstructural feature, the discontinuity.... the defect which initiated the fracture.”

Some years ago, one of the authors examined a drill bit which had fractured during use and resulted in an eye injury. It had been examined by two metallurgists. One perceived



a surface defect. Another expressed concerns regarding the microstructure. A memo was sent to the management castigating them for purchasing these cheap drills. Nobody considered that when the unstoppable force (an automatic drill press set at a given feed) encounters an immovable object (tip of the drill is dull and stops cutting) something has to give. Besides, the operator had been breaking drills all morning.

As those readers who have been involved in any type of products liability litigation recognize, the word “defect” gets the attention of lawyers. While the laws of each state will differ somewhat, it is usually the case that those involved in the design or manufacture of a “defective” product will be liable to parties injured as a result of the defect.

Point One: When materials engineers complete their education and leave academia, they must stifle their natural inclination to speak in the terms of crystal

defects, surface defects, and the like, and only use this word “defect” when there is a true defect.

Question: What is a “true defect?”

Before we get too far into this discussion, we should note that many technical terms used by failure analysts are defined in various publications by professional societies, such as ASTM and SAE. Some of these groups have a formal approval process. However, ASM International does not have a formal consensus approval system for terms published in its glossaries. Thus, there may be confusion, inconsistency, and various interpretations.

The ASM Dictionary<sup>1</sup> defines the term “defect” in two ways:

“1) A discontinuity whose size, shape, orientation or location makes it detrimental to the useful service in which it occurs; and 2) A discontinuity or discontinuities which by nature or accumulated effect (for example, total crack length) render a part or product unable to meet minimum acceptable standards or specifications. This term designates rejectability.”

These two definitions are inconsistent. The second definition states clearly that a “defect” is cause for rejection, but the first definition states only that the defect is detrimental to performance. How detrimental? Sufficiently detrimental to cause rejection?

A second complication arises with the phrase “cause for rejection.” Cause for rejection may be cosmetic (e.g. the wrong color), and have no implications as the chemical or mechanical serviceability of the component. Alternatively, the component may contain crack like imperfections, be of the wrong size, or other factors that would influence serviceability. Surface finish could be in either category. We recognize that surface finish may affect fatigue strength, but if the component is not loaded cyclically, there is little likelihood that surface finish will affect performance. Rejection for failure to meet specifications is still possible.

The ASM Dictionary also defines the term “imperfection” in a manufactured product, stating in part that (1) “an imperfection must be rated on a scale of severity in accordance with applicable specifications to determine whether or not the part...is of acceptable quality.” And (2) “the presence of an imperfection does not imply nonconformance (i.e., with specifications), nor does it have any implications as the usability of the product.”

The obvious implication is that all defects are imperfections, but not all imperfections are defects. Thus “imperfection” doesn’t connote something quite as imperfect as a “defect.” When should terms such as “imperfection,” “deviation from ideality or perhaps “discontinuity” be used in place of the term “defect?”

More recent definitions have attempted to clarify matters:

“A product contains a manufacturing defect when the product departs from its intended design...”<sup>2</sup>

and

“Defect. (1) An imperfection that is cause for rejection from an inspection protocol, or an imperfection that is shown to be a significant contributing factor in a service failure. An example is a deviation from specification. It can be the cause of a failure that makes the part unsuitable for its intended purpose. However, just because a part fails does not imply that it contained a defect, and not all defects are a cause for failure. (2) Laws of various jurisdictions may also define what constitutes a defect or defective product.”<sup>3</sup> Regarding fracture related failures, the development of the concepts of technical or physical “root cause,”<sup>4</sup> using quantitative assessment of load carrying capability, have made possible a more definitive description of cause, and allow us to determine whether a perceived defect is a cause of a particular failure.

In order to determine whether a potential defect is in fact a defect by this last definition, we may use the following mental process:

First, we recognize that local imperfections may be present in the material. These may be geometric (nicks, gouges) or material related due to variations in processing.

Imperfections, or deviations from the ideal, are often found in the course of a failure analysis. One of the essential questions that the failure analyst must answer is whether the imperfection is a significant factor in the failure happening the way it did.

A quench crack is an example of an imperfection created during thermal processing when internal stresses cannot be relieved by plastic deformation. If failure of the component resulted in fracture, and the crack that lead to fracture did not propagate from the quench crack, the quench crack is an imperfection, but not a defect.

Imperfections created in one stage of manufacture may or may not be removed in a later state. Examples include the formation of internal cavities during forging, but which may close during further deformation, shrinkage porosity in an ingot which may or may not be closed during subsequent working, and the creation of laps during forging.

During the course of a failure analysis, there are several questions that must be answered:

(1) Was the component or another component from the assembly used in a manner not intended by the designer?

(2) Was the design procedure and manufacturing sequence performed properly?

(3) Is there evidence that there were unexpected conditions to which the component or assembly was subjected?

The process of the failure analysis is to answer these questions. It must be emphasized that the process of the failure investigation may well, and usually does, reveal some condition in the material or product that is not ideal, and we say that an imperfection is present. The question then is, "Should we call the imperfection a defect?"

### CONCEPT OF PHYSICAL ROOT CAUSE

Assume that macro and micro scale examination or hardness testing has shown the presence of material imperfections. Unless the imperfection can be shown to be the cause for failure, the imperfection is not a defect. For example, a change in cross section of a component results in a stress concentration at that location, and this then often becomes the site of crack initiation if fracture occurs. Is the stress concentrator a defect ?

That depends, and there are two possible answers. Assume that the drawings for the part indicated a minimum fillet radius at the change in cross section. Assume then that the fillet radius measured on the broken part was smaller than the fillet radius called for on the drawing. Is the manufactured fillet a defect? It is a *defined* defect in terms of the drawing specification, and if this question were being litigated in court, the plaintiff attorney would likely argue that the component was defective because of improper manufacture. However, it has not yet been shown by stress analysis that the decreased fillet radius caused the allowable stress to be exceeded for the specific material (microstructure) in question. When the stress analysis shows the allowable stress to be exceeded, the imperfection has become a true defect and the physical cause for failure has been identified. Without the stress analysis, all that is known is that the part failed at a location of stress concentration. The location of failure is not at all surprising, and identification as that location as a "cause" for failure is incorrect. Perhaps the part was grossly overloaded. The part will always fail where the internal local stress created by the applied loads and geometry cause the local strength of the material to be exceeded.

If the imperfection or discontinuity did not MOVE the crack initiation from its expected location, (that where the design process identified the maximum local stress) due to movement of the location of maximum local stress, we must exercise great caution in calling that deviation a defect in any sense of the word.

It is worth saying again that macro scale crack initiation sites can be predicted based on stress analysis. If the initiation site is not in the location predicted by the assumed useage of the component, something had to change the location. Possibilities include unexpected (inappropriate?) useage, inappropriate microstructure, or an unanticipated geometric imperfection was present. An example often used by one of the authors is the fracture of a screwdriver. Screwdrivers are often inappropriately used as pry bars. Design useage creates torsional loading, but prying creates bending loads. The fracture surface is different for the two loading conditions.

Another of the authors examined a cylindrical part designed by a scientist, not an engineer. A change in radius had been drawn as a square corner. The machine shop attempted to make it like the drawing and was able to achieve a fillet radius of about 0.002 inch. While the problem was clearly with the design, what was remarkable was

the considerable effort required on the part of the machinist to achieve the perceived drawing requirement. In this case a manufacturing defect, i.e. deviation from drawing, might have compensated for a design defect, a stress concentrator which made the part unfit for purpose.

### Design versus Manufacture

There is one more consideration, however, that failure analysts need to consider before using the word “defect,” or even sometimes the word “imperfection.” Many manufacturers supply component parts to larger companies. Even when it clearly has been quantitatively demonstrated that an imperfection was the major factor or even the “single cause” of an “unexpected” failure, using the word “defect” may initiate a chain of events which culminate in the “wrong” party getting “blamed” for the “defect.”

The issue of design responsibility today can sometimes be very “fuzzy.” Companies may put out a request for quote for large quantities of components to be supplied by job shops. The job shop employees often have little knowledge of the actual stress and environmental resistance requirements of the component. Many times the customer specifies, for example, “1008 / 1010 Steel.” Often, the detailer does not even specify “AISI” or “SAE” 1008 / 1010 Steel. It is possible that the designer is not even aware that there is an organization responsible for publishing steel composition standards. Such designers are also often unaware that this designation is strictly related to composition. It does not have any significance regarding mechanical properties or freedom from discontinuities. In such a case, the supplier may buy the lowest cost material available. For bar stock, this is usually something that ASTM calls “merchant quality” steel.<sup>5</sup> Basically, this is “steel that sinks in water.” It is intended only for non-critical applications. This grade will typically have more discontinuities than that supplied to the more stringent specification, which requires surface conditioning “as necessary to remove injurious surface imperfections.”<sup>6</sup> The discontinuities in merchant quality bar may make it unsuitable for use in applications requiring long term structural integrity, especially if there are dynamic loads and significant safety or financial issues related to premature failure.

So let’s say that small Company A bids on the project and starts making the components. They sell the components to Company B, a medium sized firm which bills its engineering department as “state of the art” to Company C, the large firm which will install the assemblies containing Company A’s components into their products.

Now, a year down the road, there is a failure. An obvious imperfection is detected, which has clearly been proven to be the physical cause of the failure. That is, there is a quench crack in the carburized layer of the 1010 steel component. The main crack propagated from the quench crack, and fracture mechanics demonstrated that it would be impossible to overload the assembly to the degree necessary to have had a crack propagation event in the absence of the quench crack.

Further, let us say that the presence of the quench crack has been associated with laps and seams in the original 1010 steel material. So what does it accomplish to call the

quench crack a “defect?” How does it help us to call the lap that “caused” the quench crack a “defect?”

Perhaps the designer’s budget only allowed use of merchant quality steel. Perhaps the designer was UNAWARE that there are different quality levels of steel to be purchased, some of which are guaranteed to be free of laps and seams. And by the way, who was really responsible for the design anyway?

In this case, there is really not a manufacturing nor a materials defect. The end user got exactly what they paid for. If no prohibitions of laps, seams, quench cracks or other imperfections were SPECIFIED on the print, and if the critical nature of the application was not otherwise communicated to the supplier, the words “defect” and “imperfection” should be reserved for the design process, or perhaps even more so, the management system which did not include adequate materials engineering review. The defect is not in the physical component itself nor in its characteristics.

Point 2: Before using the term “defect,” think about exactly what you are trying to convey. Do you merely mean the item deviates from one aspect of a specification, or do you mean the item failed because it was unfit for its purpose, i.e. truly defective? Be particularly careful about using the term to refer to physical characteristics that may imply fault where fault does not lie.

### *Disclaimer*

This article has attempted to cover multiple sides of a complex issue in a thought provoking manner. The article is intended to stimulate discussion and careful thought to foster clear communication. Opinions have been expressed by the authors for this purpose and are not necessarily shared by their employers, colleagues, clients, ASM International, or the editors of Failure Analysis and Prevention. Readers are invited to contribute their own ideas in letters to the editor or articles submitted for publication. To start off the discussion, the authors asked Dennis McGarry, SEA Limited, Columbus, Ohio, to comment on our article.

1. ASM Materials Engineering Dictionary, J. R. Davis, ed., ASM, 1992
2. INSERT TITLE, AUTHOR, Preventing Failure Through Education: Getting to the Root Cause, Conference Proceedings, ASM International, J. Scutti, ed., ASM International, May 2000.
3. ASM Handbook, Volume 11, Failure Analysis and Prevention, 2002
4. The term “root cause” is probably used in as many different ways as the term “defect.” See Yahoo Groups Root Cause forum ([www.yahogroups.com](http://www.yahogroups.com))

5. ASTM A575 for Steel Bars, Carbon, Merchant Quality, M-Grades and ASTM A576 for Steel Bars, Carbon, Hot Wrought, Special Quality.

6 ASTM A576 for Steel Bars, Carbon, Hot Wrought, Special Quality, Section 7.2