STEEL FOUNDERS' SOCIETY OF AMERICA

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Understanding Steel Casting Failures

All parts, regardless of their product form, be they castings, forgings or fabrications will fail if the service load exceeds the design limits. The load bearing capacity of a casting depends on the geometry, material properties (strength) and quality. Selecting these requirements is the responsibility of the design engineer. The casting producer must meet the requirements specified.

Routine part failures generally indicates either one or a combination of ~~a~~ inadequate geometric design, incorrect material selection or failure to select the quality requirements which might include NDE requirements, the net result is that a redisgn is required. A sporadic part failure indicates the part was not capable of meeting the load required; which may be due to a an unplanned use or a quality issue that may or may not have been identified as a requirement for the part.

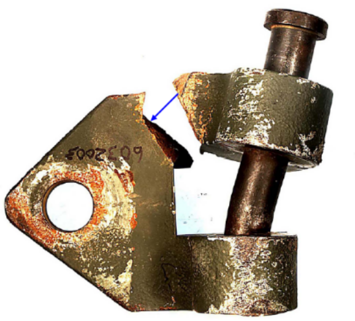

Figure 1

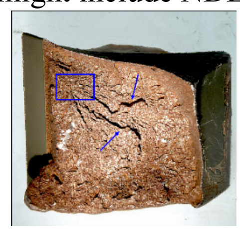

Figure 2

It is common for a failed part to be sent to a laboratory for inspection and analysis. The fracture surface is examined and the initiation feature and crack path are determined. Pictures are taken and a report is written. Unfortunately, this does not address the main issues: did the casting meet the specification requirements, did it meet or exceed the design loads, was the design adequate for the service conditions, or did the part experience abuse with loads that exceeded the design?

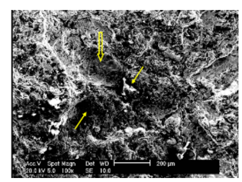

Figure 3

Steel casting are used to make complex shapes. As the design becomes more complex in shape, the load is highest at and is constrained to the smallest cross section subjected to that load. When a part is loaded in excess of its capacity, it can fail in a brittle manner in the heavily loaded section without obvious deformation as the failure path is determined by the complex part shape and the load, Figure 1. Often the fracture surface at the microscopic level shows ductility but the crack path will be flat without any macro deformation due to the geometric constraint. The initiation of failure will be at the weakest, most heavily loaded feature and will propagate through the weakest material Figure 2. A test laboratory that examines the failure path is expected to find an initiation point and areas of weakness that limited the capacity of the part, Figure 3.

All parts can be loaded beyond capacity and fail. The failure will occur at the weakest area of the heavily loaded section of the part. The weakest area will have a feature that initiates the failure. Common practice is to identify this initiation feature as a defect and attribute the failure to its existence. This is often incorrect since the part load may have exceeded the design intent due to an inadequate design or product abuse. Labeling the initiation of failure to a defect incorrectly and prematurely assigns responsibility of failure to part quality and fails to correctly identify the root cause or commercial responsibility.

All real materials have features that limit the capability of the part. In the ASTM nondestructive testing standard E1316, the definition of a defect is, "one or more flaws whose aggregate size, shape, orientation, location, or properties do not meet the specified acceptance criteria and are rejectable." In this definition the correct commercial and technical use of the term, defect, is a condition that violates the purchase requirement at the transfer of ownership from the producer to purchaser. A flaw in the part that initiates a failure due to excessive load is only a defect if it was required to be inspected for and was able to be identified by the inspection and exceeded the purchase agreement acceptance criteria.

The producer is responsible to meet the purchase requirements for the part supplied. The designer and purchaser are responsible to identify the purchase requirements that will make the part adequate for its intended use. The producer is supposed to meet these requirements in the part.

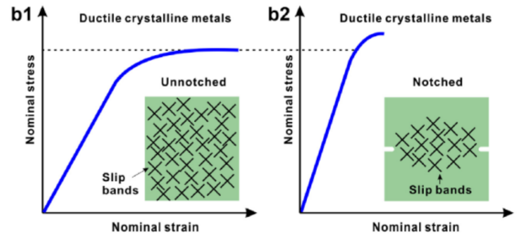

Figure 4

When a feature is seen in the fracture surface of a steel casting initiating the failure, the assumption is that it degraded the strength and led to a premature failure below the performance expected from the design. For steel castings that have complex geometries and material ductility, the notch effect of geometry and the flaw may not decrease the load carrying ability and can even lead to increases in the load required for failure. This is seen in ductile steel materials in general, (http://www.jmst.org/EN/abstract/abstract22560.shtml#). In Figure 4, you can see that the notched sample exhibits higher strength and less ductility for the same steel that has no notch.

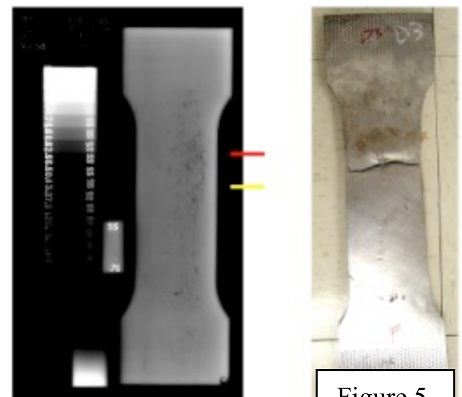

Figure 5

Steel castings with porosity show the same type of behavior, samples with porosity have strength comparable to sound samples, (http://user.engineering.uiowa.edu/~becker/documents.dir/Hardin_2013.pdf.) In these tests, samples with radiographic indications that were half the width of the test specimen, the tested samples still had yield and ultimate strengths that exceeded the specification minimum as seen in Figure 5 and Table 1.

Plate	Maximum Indication fraction %	Ultimate Tensile Strength (ksi)	Yield Strength (ksi)	Elongation %
ASTM A216 WCB	N/A	70 to 90	36 min	22 min
sound	N/A	80.65	51.76	22.0
D2	45.19	83.05	55.65	16.0
D3	50.00	83.49	56.35	16.3
D4	44.23	80.41	54.39	12.8
D5	35.58	83.51	54.15	17.1
E1	42.31	78.61	47.75	19.6
E2	45.19	81.52	53.38	13.8
E3	50.96	77.17	51.53	15.0
E4	57.69	76.24	52.52	13.8
E5	51.76	80.65	50.65	17.0

Table 1

All parts and materials including steel castings will fail if loaded beyond their capacity. All parts and materials, including steel castings will fail in the most heavily loaded section and the failure will initiate at the weakest feature in that section.

If the casting did not meet the purchase requirements and the failure is due to a specified defect, the casting is defective and the producer is responsible.

If the casting met the purchase requirements and the casting failed because the user abused the equipment, the user is responsible.

If the casting meets all the purchase requirements and was not abused, then the design was inadequate and responsible for the failure. The change in design to mitigate the failure could involve change in part geometry, material, manufacturing, or quality requirements. Appropriate design changes must address the excessive load that caused failure. Analysis of the failure surface to understand the cause of failure is necessary but not sufficient. Identifying and eliminating the "defect" that initiated failure may or may not resolve the problem.

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