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Factors that Influence Casting Life

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Every person who operates a shredding plant has experienced casting failure, or shorter than expected life, of a casting at some time. Most often when this situation is investigated, the manufacturer of the casting will report that the problem was not the fault of the casting itself. It is frustrating for the operator to hear this, but at least 9 times out of 10, it is probably true.

The following is our attempt, to list as many as possible, of the factors, which affect hammer, grate and liner casting life. We hope that by carefully understanding this list, we will be able to help the operator identify the cause or causes of the failure or the change in the wear life, which have been experienced.

The first items of information which most people seek when trying to understand casting life is the chemical specification and the heat treatment of the casting. This is also the first place where we look. That is why we often request a sample of a casting to be sent to us for analysis. We check the chemical analysis with our spectrograph and carbon determinator. Examining the micro-structure of the casting through a high-power microscope checks the effectiveness of the heat treatment.

It has been a long time since we have found one of our castings with the wrong chemical analysis. This is because we charge the furnaces with known analysis materials and then during the melting cycle of each heat a thorough analysis is made before the molten material is poured from the furnace, thus allowing corrections to be made as required. After corrections have been made the material is poured into a ladle at which time another analysis is made. This is what we call the final analysis. Both the preliminary and the final analysis are recorded in our records.

The analysis work utilizes a spectrograph and a Leco carbon determinator (whose accuracy exceeds the spectrograph as far as carbon levels are concerned). It is, of course, always possible that an error can be made, even though we are doing everything within our knowledge to prevent anything from going wrong. A chemical specification type of error is very rare. However, should an error occur, we will definitely be able to identify it during a subsequent analysis of a casting that does not achieve an expected useful life.

The heat treatment cycle is under the control of programmable digital controllers, thus eliminating a lot of the human element. We carefully heat treat castings of various thicknesses according to proven schedules of heat soaking at various temperatures. Manganese castings require a very slow increase in temperature from room temperature to 1950 degrees F., where they are “soaked” for about one hour for each inch of thickness. This changes the grain structure of the casting from martensitic to austenitic. At that point, we take the castings from the furnace and put them into an agitated water quenching tank. This transfer from the furnace to the water must take place in approximately 45 to 60 seconds. If this is not done properly, carbides will migrate from the grain to the grain boundaries and the casting will not have the appropriate strength and toughness. When this is done properly, the austenitic grain structure is fixed and the casting becomes tough and is then capable of being work hardened.

Again, however, even though the occurrence is rare, an error is possible. On a random basis, we select a casting from the finished product, cut it apart, and subject it to a rigorous examination as to microstructure. This is another reason we request samples of any questionable casting be sent to our lab for analysis. We do not often find a problem but, when we do, it almost always is limited to a very few castings.

In the past year, we have not identified any problem, which indicates that we need to alter the standards for chemical specification or the heat treatment of the castings being produced.

If a problem is experienced with a complete set of hammers or a complete set of grates or liner plates, then it is believed that rather than being a specification problem, the most likely answer can be found in one of the two other variables -- the type of material being shredded or the mechanical questions of shape and size of all parts involved.

The biggest single variable, that affects casting life, is the material that is being processed by shredding. The most dramatic event is the inclusion of an massive unshreddable in the material fed into the shredder. This can cause breakage and shorter life to any of the castings in the machine. It has been noted that the damage done by an unshreddable does not always show up immediately, sometimes it appears several days after the event.

There have been significant changes to the types of material that are being shredded over the past few years. We still shred complete automobiles and various amounts of appliance and miscellaneous scrap, but we have added a full range of heavier scrap. This heavier scrap contains a higher percentage of unshreddables and requires tougher shredding machines and tougher and better designed castings.

Unshreddables are one of the variables, but another variability concerns the type of scrap being processed for a relatively short time period, for example, the time period when the scrap and dirt accumulation from the bottom of the stockpile is processed. When this happens perhaps one set of hammers will not produce the expected tonnage, but this most probably will not explain a long-term variation.

A long time period variable might be something like a significant increase in the amount of waste material such as upholstery, dirt, rubber, etc. which gets included in the steel scrap to be shredded. For example, if the weight loss from unprocessed to shredded material were to go from 20% to 33%, a significant amount of extra material would have been shredded, even though most of us measure our casting life in tons of steel scrap shredded.

Almost everything else, which affects the casting wear life, is related to the density of the finished shredded steel scrap product. Density is dependent upon the type of material being processed and the number of hits, which the scrap takes, both from hammers and from the other castings in the shredder. It should be noted that not all hits are of the same efficiency -- we guess that some of the hits cause more wear and less work than others. We believe that the efficiency of the hits is one of the most important factors in explaining unusual or variable casting life times. An increase in density over a period of time is one of the things, which can explain a change in casting life.

Our normal casting consumption projections have been made with a product density of 65 pounds per cubic foot. This density should be produced with approximately 14 to 20 KWH of electrical consumption depending upon the size and efficiency of the shredder. With the larger sizes of shredders the amount of KWH required to shred one ton decreases.

The dry downstream separation system will consume another 15 to 25 KWH, while a wet separation system will use another 5 to 10 KWH, depending upon the number of motors in use, etc. If a shredder consumes more than this amount of KWH per ton for shredding, and density is not appropriately high, then some of the hits probably have not been of the right type and have not been efficient as they should have been.

We do not know exactly how much KWH is required to produce more density, but we do know that it varies from machine design to machine design. The TBD (top and bottom discharge) shredders produce shredded scrap with a given density with less KWH than the TD (top discharge) shredders or BD (bottom discharge).

The KWH required to produce an increase in density will not be a straight line increase. For example, the increase in density from 65 pounds per cubic foot to 75 pounds per cubic foot represents a 15% increase in density. The KWH required will be more than 15%; it will probably be 30%. A 20% increase in density may require 50% more KWH of electricity. As the density increases the KWH required will increase on a steeply progressive curve. In the same way, as density is increased, the casting will show increased wear and shorter life per ton of scrap shredded. Again, the wear factor will change by something more than the direct change in the density.

Some of the factors effecting density and the efficiency with which the density is obtained, and thus casting wear, include:

1. Internal clearance between the hammers and the wearing castings affects the life of castings. We believe that excessive internal clearance leads to inefficient hits on the scrap, and thus, more casting wear per ton of steel scrap produced. It should be noted that insufficient internal clearance causes hammer stretch and breakage, and pin shaft wear and breakage. This is because with insufficient internal clearance the hammer tends to “bounce” off of anvils, liners or grates and the hammer moves violently back toward the pin shaft. Since manganese castings deform with impact (this provides the work hardening attribute) the hammer pin hole can stretch. This allows the hammer to have even less internal clearance than during the previous revolution. This leads to a “run-a-way” situation with less and less internal clearance until there is an interference, which will result in

casting failure. When we see stretched hammers, we always look first for insufficient internal clearance. There are other reasons for stretched hammers that are covered in the section regarding casting failure.

The standard minimum internal clearance in most steel shredders is 1" in top discharge (TD) shredders, 1.5" in the top and bottom (TBD) shredders and 2” in Super Heavy Duty (SHD) shredders. There is no standard maximum clearance because excessive clearance does not cause breakage; rather, it causes only loss of efficiency. The operator is usually in the best position to make the economic decision as to when the castings require replacement.

In at least one situation of low liner plate life in a TD shredder, we found that the floor of the shredder had bent down so that excessive clearance existed between the hammer circle and the floor plates. This led to an unsatisfactory wear rate for those liner plates and for the hammers that were being used.

2. Grate Sizes. Size of the grate openings and the percentage of open spaces in the grate compared to its total area affect the efficiency of the shredding operation.

3. Reject Door. Operation of the reject door and the amount of open space averaged can raise or lower density and casting consumption.

4. Design of the Hammer. We believe the bell-shaped hammer maintains a better center of gravity, thus improving the efficiency of the hits throughout the hammer cycle. The bell-shaped hammer has more casting weight in the hitting area; consequently, the ratio of the amount of casting purchased to the amount of casting discarded is improved, resulting in a lower cost per ton for casting usage and replacement. Recently, weight efficient hammers have been developed that remove some of the casting weight from parts of the hammer that would normally be thrown away. This series of hammers are designated as being WE (weight efficient) hammers.

5. RPM of the Rotor. During the last few years, we have found that the RPM of the rotor affects the rate of casting wear. In general, a slower RPM yields a longer casting life. There is a trade off however, in productivity. Higher RPM's create more striking force and better shredding characteristics.

6. Length of Usage/Casting Wear. Length of time, which the hammer and other castings are used, and the amount of casting metal, which is worn off is another factor affecting casting life, as expressed in tons produced. Castings are normally replaced at the decision of the shredder operator based on his own set of criteria. Some operators will use castings longer than other operators based on the operator’s perception of how well the shredder is running. Some operators value long life more than tons per hour output. There is a large variance in how operators make this decision. Changing castings too soon results in low life and changing them too late may result in exceptionally long life being reported, but with very reduced tons per hour capacity for the shredder. In normal situations, we believe the hammers can be worn so they have less than one-half their original weight remaining before being discarded.

Since length of usage is such an important area, it will be useful to discuss normal casting change procedures.

Below are some of the main items to check:

1. Under normal conditions, running automobiles, hammer life varies according to the size of the shredder and the size of the hammer that it is possible to fit into the shredder. In disc type battle rotors with 10 hammers arrangements, 80104 SHD hammers should last 1200 to 1500 tons per side, making a total life per set of 2400 to 3000 tons. In the 98104 SHD hammers will last about 2400 to 3000 tons per side for a total life set of around 5000 to 6000 tons. In the 120104 Megashredder, the hammers will last about 5000 tons per side for a total life set of around 10,000 tons.

   The set of hammers should be changed when they have worn to the point that production falls or when the hammers are worn unevenly so that the rotor becomes unbalanced. Some operators have found that if some of the hammers are changed every day, that the balance of the turning rotor and the hourly production of the shredder and the density of the product is more consistent.

   When using a spider rotor with more hammers we find increased tons per set but lower tons produced per hammer. Overall however, an interesting fact is that efficient shredders, all use about .5 pounds of hammer worn off of the set for producing about 1 ton of shredded scrap with a density of 65 lb/cu/ft (Specific gravity of 1). For example, if a shredder produces 10,000 tons of scrap, we believe that about 5000 pounds of hammers will have been worn away.

   We have made this calculation many times and it almost always comes back to the same .5 pound worn away. Not all hammer designs will allow for a 50% usage. For example, Super Heavy Duty hammers, where there is a larger amount of casting around the pin shaft to provide enough strength in the hammer will not achieve 50% “throw away” weight.

   This means that if we are able to achieve a 50% "throw away" weight, that it takes 1 pound of casting to shred one ton of finished product. When the “throw away” weight is higher than 50% then it will require buying more than 1 pound of hammer casting per ton of finished product.

   As a matter of interest, we have found that the total amount of casting weight that must be purchased for the shredder is about 2.2 pounds per ton of material processed (or about 1 kilo of casting per metric ton of shredded scrap). This indicates that overall, the "throw away" ratio is slightly more than 50% for the shredder's complete operation.

   Hammers are designed so that the maximum amount of material can be worn away before the hammer must be removed from the shredder. The main constraint on lower "throw away" weight is the amount of casting that is required around the pin hole to keep the hammer in the shredder through the life of the hammer. When shredding heavy scrap and when shredding bales, we have decided that a good compromise is to increase the amount of metal around the pin hole, even though this worsens the "throw away" ratio.

Some hammers may have to be replaced on a random, as needed, basis due to irregular wear, cracking, or other reasons. Such a condition or situation may dictate that the opposite hammer also be replaced to maintain the rotor's proper balance. Replacing worn hammers, as needed, and the replacement of all hammers, as scheduled, for rotation will generally help maintain the rotor and shredder operation at peak efficiency.

NOTE: Good record keeping and a good visual inspection by a qualified operator can usually determine what hammers or pairs of hammers may need to be replaced even before the procedure begins.

2. Liners should be replaced when they have worn so thin as to expose the bolt head or be in danger of breaking. The liners wear at different rates, but in our designs they have been adjusted in thickness and shape, depending on their position inside the shredder, so as to wear more evenly and to have similar useful lives. They should, however, be inspected on a regular basis.

3. The anvil is a replaceable item that should be changed when the cutting edge wears far enough away from the hammers to significantly change production rates and the begins to affect the density of the finished product in an unacceptable manner. Normally, the anvil section will last about the same as the bottom grates.

4. The reject door is subject to wear across its bottom edge resulting in a bowed shape. It must be built up or replaced when it has worn to the point that its effectiveness is reduced. This usually occurs when a door has worn off 4" to 8" (100 to 200 mm) or becomes bowed beyond its ability to function properly. The symptom will be an excess of oversize material in the product due to their escape through the reject area, having bypassed the grates.

5. Pin protectors will need to be replaced when their teeth have worn off and they no longer afford protection to the disk or when they have worn enough to be in danger of breaking or when they do not properly protect the pin they surround.

6. When "saddles" have worn into hammer pins where the hammers have swung, the pin may be switched to a location where the hammers fall on an unworn portion of the pin: this will let the pins be used for a longer period of time. Hammer pins should be replaced when they have had a hammer run in each location.

7. The grates can be replaced as necessary. This means that the grates should be checked regularly to ascertain when one or more have worn to the point that there is danger of breaking. As grates fail away from the rotor, many operators run their shredder until the grates have worn so thin that a failure occurs. This insures maximum utilization of the casting but this system must be balanced against tons per hour and density considerations.

Grates should be routinely inspected for wear and/or broken or cracked areas. Grate wear will vary with a) the type of materials being processed, b) the density of the finished product being produced, and c) on the production rate desired.

The most efficient design for a set of grates seems to be a set with the first 3 or 4 grate bars being made 1 inch thicker than the following 4 or 5 grate bars. This is because the first bars always wear more quickly than the following bars and when the first bars are worn out, the last bars still have another 30% to 50% life left in them. By using a set with thicker bars up front, the set of grates tend to wear out more evenly and at the same time. This normally provides a more economical cost per throughput ton for grate bars.

Typically, grates used with grate supports will need to be replaced when 40% to 50% of their original mass has worn away. In grate sets where the grate itself provides its own support, the "throw away" ratio is higher because the part of the casting that provides support must be replaced as a part of the grate bar that is being replaced.

Other factors can also affect when a grate should be replaced. Indications of excessive grate wear may include:

1. The appearance of large cracks in the grates. This symptom provides an obvious indication and need for a grate change.

2. A noticeable drop in shredder efficiency, a dramatic change in scrap density, or the balling of softer materials, etc. If efficiency is not restored even with the installation of new hammers, etc. the grate wear may have created excessive gaps between the hammer and grate surface. This gapping condition will affect both product density and production rates.

Other major work should be scheduled along with any grate exchange to take full advantage of the significant downtime associated with their replacement. Since grate hole or aperture size is a prime factor in determining product density, it is also suggested that consideration be given, when ordering new or replacement grates, to adjusting the grates to improve the performance of the shredder or affect a change in the grade or density in the final product.

Failure Analysis

If the answer to a casting failure has not been found in the above list of mechanical factors, then it can probably be found in an analysis of the casting itself.

Chemical Analysis

The chemical analysis of manganese alloy used in most shredder applications is a variation of Hadfield manganese steel alloy, which was invented in the 1800's by a Mr. Hadfield of Shefield England. This type of manganese alloy has proven to be a wonderful steel for impact and abrasion type of applications, with characteristics that provide for maximum forgiveness for the user of the casting.

In general, this is a steel alloy with 12% to 14% manganese added. The carbon content is usually within a range of 1% to 1.2% and various other carbide producing elements such as vanadium, chrome, nickel and moly are added in small amounts, according to the recipe of the specific foundry making the casting.

The alloying agents must be kept within narrow ranges to produce the same quality of casting on a consistent basis, because rather small changes in the carbide producing elements affects the required heat treatment significantly.

The typical procedure requires the person, who is in charge of the melting of the material in the electric furnace, to make calculations as to what to add to his "cake mix" of material that will be charged into the furnace.

He must calculate how much to use of scrap steel, the quality of scrap steel, the amount of return scrap (used castings and internally generated scrap such as the riser, which has been cut off of the finished casting), the amount of new manganese ferro alloy and the amount of the various alloying agents that must be added. Of course, this has been done so many times, that everyone knows exactly how much of each material must be charged into the furnace in order to come close to the final analysis that is required.

When the material has been melted, which is nearly one hour into the melting process, an analysis is taken. Then further calculations are made as to the amount of and type of alloys that must be added to bring the heat to the exact specification required. The alloys are added and then the melt is checked again, for what we hope, and assume, will be the final analysis for that particular heat.

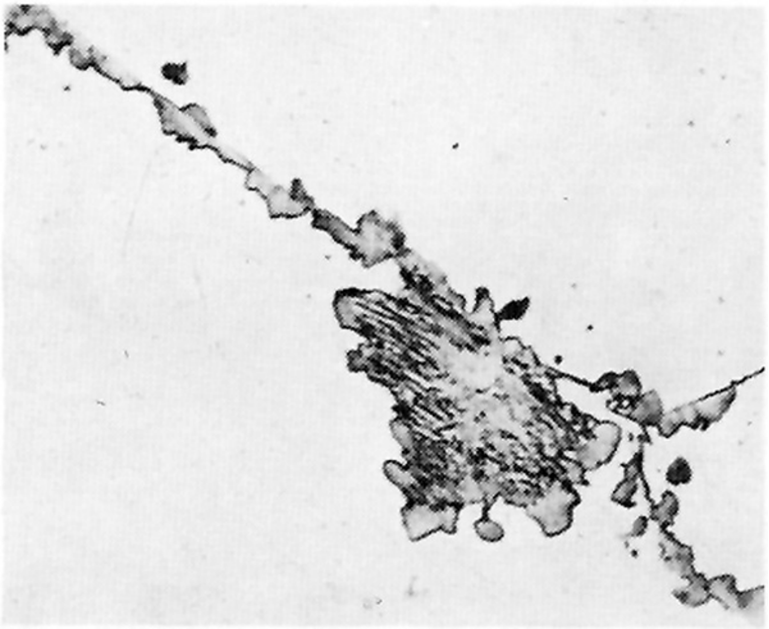
Micrograph Analysis

The most significant change to the our foundry procedures came after a powerful microscope was added to the laboratory equipment. Through proper microscopic analysis, the entire history of a particular casting can be learned. In combination with the chemical analysis, it is possible to determine if the heat treatment procedure was carried out properly, whether the casting has been work hardened, which is a characteristic of austenitic manganese steels.

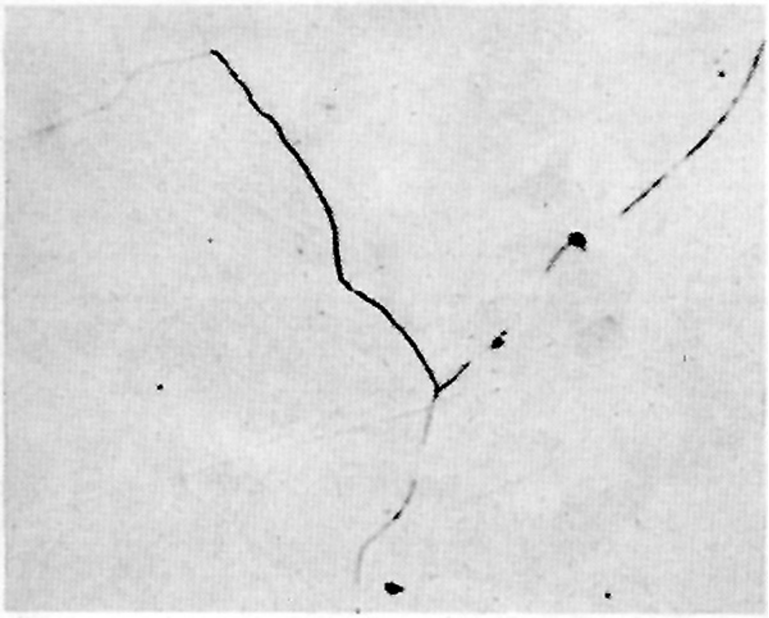
The most important thing that is checked with the micrograph is the position of the carbides that are in the alloy. The ideal is that the carbides will be incorporated into the grains of the casting with only small amounts of those carbides remaining in the grain boundaries. (See picture #2). When the casting is as poured, large amount of carbide material is located in the grain boundary. (See picture #1). When excessive carbides are in the grain boundary, the casting will not have as much strength and is much more likely to break. Those carbides tend to weaken the bond between the grains.

In the sample micrographs that follow, it is possible to see the grain structure of various manganese castings.

Picture #1 shows a sample of manganese alloy casting that has not been heat treated. The carbon is very evident in the grain boundaries.



Picture #2 shows a sample from a hammer that has good characteristics. Note that the carbon has been absorbed into the grain structure and that very little remains in the grain boundary.



Summary

Manganese alloy steel castings are a tremendous help to those of us who are trying to make profits by operating shredding machines. These castings are economical to purchase and use, and they are forgiving when subjected to heavy unshreddables.

So the next time that a casting failure is experienced, remember to check the list of things that can go wrong, and send a sample to the foundry laboratory. Hopefully, an explanation can be found that will allow for correction of the problem.

It always possible that no explanation can be found and that the failure is the result of an accident, or random occurrence, such as an inclusion. This seems to be the situation in about 1 casting out of every 10,000 that are made. Normally, this kind of failure rate would be impressive, but our goal is to have zero unexplained casting questions.

We will continue to conduct an analysis of castings that fail and we will continue to analyze castings that do not fail so that we can prove to ourselves what it is that works and what it is that does not work. Changes to composition, or heat treatment procedures, are done very slowly, and with great care, so that only one change is made at a time. Through our fortunate connection with so many good shredding operations, it is possible for us to monitor the progress of a specific experiment.

The stated goal for The Shredder Company, LLC is to make constant improvement in our products, and in our productivity, and we intend to pursue these goals with a policy of involving our employees and our customers with the process of improvement. With more information, every one is better able to help.

Therefore, with a thank you to Mr. Hadfield, and to the many users of our castings, we will continue the journey toward production and use of ever better castings.