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EQUIPMENTS FAILURES AND ITS EFFECTS ON HEAT TREATED PARTS[1]

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Abstract

The aim of the present work is to indicate a resolution way for heat treatment problems showing examples that happen in heat treatment shops, in house heat treatments, furnace manufactures and technical assistance companies in the area; the examples and case studies are also related to interface areas as Atmosphere, Time, Temperature, Heat distribution homogeneity and Equipments.
Key-words: Failures; Atmosphere; Heat treatment.

FALHAS EM EQUIPAMENTOS E SEU EFEITO SOBRE PEÇAS TRATADAS TERMICAMENTE

Resumo

O objetivo do presente trabalho é indicar o caminho para resolução de problemas em tratamentos térmicos com exemplos ocorridos em prestadores de serviço, fabricantes de fornos, assistência técnica e plantas de tratamento térmico "in house"; os exemplos e estudos de caso abordados têm a sua interface nos pontos de Atmosfera, Tempo, Temperatura, homogeneidade de distribuição de calor e Equipamentos.
Palavras-chave: Falhas; Atmosfera; Tratamento térmico.

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1 INTRODUCTION

Often heat treatment production and process people are faced to some metallurgical problems that seem to be not possible to occur since the procedures are done and confirmed, all parameters previous developed and confirmed are in good term and materials quality and equipments are approved according to standards and routine work. Some questions appear; what about initial forming? Do we have checked if the final finishing has been performed in accordance to the previous granted parameters? What was the stock removal? Do we check core hardness? Are sharp corners present?[1]

Suddenly we do not know where to go and then the big problem start. At this time usually we remember to take time, evaluate the scenario and establish a frame.

Several tools and methodologies for this approach are well spread and done as example problem solution analysis, root cause evaluation, TOPS 8D (Team Oriented Problem Solving), Ishikawa diagram, Failure Mode Evaluation Analysis, six sigma and so on. Nevertheless the final solution is not totally achieved, sometimes just quality tolls are not enough due to new events that usually appears and are not so clear or wrong interpretation have been done from solution problems tool experts with not some many experience in heat treatment area at all.

The idea in this work is not to explore the tools referred but show and describe the problems that we, as heat treat production and processes people are faced to in order to help and/or give a tip about what is behind off “everything is under specification”.

In this work examples will be given real and lived problems that happen in heat treatment shops, in house heat treatments, furnace manufactures and technical assistance companies in the area.

For some process it is allied a kind of troubleshooting according to the experience and literature review close to manufactures and goods suppliers.

Some examples out of heat treat frame will be seen when the interface is applied and related to.

The idea is to look at: Equipment, Atmosphere, Time, Temperature, Fixtures, Heat transfer / exchange, Heat distribution and cleaning.

2 EQUIPMENT

Usually this issue has been evaluated at early stage of manufacturing and its demands. The selection of what heat treating equipment should be used depends upon the productivity of the part, part configuration and product property requirements. Generally, buyers are looking for compact installations, reproducible results and good performance at the lowest possible cost. However, different conditions demand different types of installations and here we have to take care. A heat treatment line is projected for some parts and specification, but specification are subjected to change, customers change, parts change and sometimes processes have to be changed too. For sure that we are not able to have everything at just one production line, but we can be up to date to see the strategic plan of the company, foresee the trend of its market and evaluate the cost benefit taking in account the versatility that is needed or the dedication for parts and/or processes.

Taking this discussion the idea is to open the view, take a time to remember or advise us for some basic points that can affect heat treatment area in general and avoid problems. Some topics will be seen in this work. At sequence some basic points at heat treating equipments:

- Wash systems should be appropriate to the component's configuration, load assembly and fixtures. Remember that this can be a source of bad diffusion due to a dirty surface, as an example.
- To avoid parts damage (example knick / parts beating) the transport systems should be smooth especially in the hot zone as otherwise the probability of component distortion as well as wear and tear of the parts is high.
- Physical damage and distortion can be also minimized maintaining drop heights as low as possible, mainly during transfer of parts from one zone to the other in continuous furnaces.
- Temperature and/or atmosphere distribution must be uniform, provided by good heat source plan, using proper heating power, fans, and muffles in order to achieve the minimum variation and according to standard or parts specification.
- At furnaces where atmosphere are needed all equipment should be leak tight and all moving parts inside the furnace should be periodically checked for leaks. This is a source of no homogeneity at parts and for sure, basic to a safety operation.

3 ATMOSPHERE

According to the processes carried out we have to use certain atmospheres and different kind of gases. Each application must be evaluated regarding corrosion, temperatures, furnace material construction and others. Some studies and researches[2] explore details, showing the oxidation and decarburizing of the carburized layer. Linked to atmosphere we can not forget the retained austenite[3,4] and its influence on wear, even this subject is still place for a lot of forward and against the influence is present and we have to deal with in a proper way.

"As the retained austenite level is increased from 6% to 30%, wear resistance is decreased at 40 kg load condition. However, wear resistance is again increased above certain critical retained austenite level".[4] Internal oxidation, High Temperature Transformation Products (HTTP) is also related to atmosphere, not just on it for sure, but a good portion is due to not optimized atmosphere. It is important to know how the inherent internal oxidation in atmosphere carburizing process comes and its effects on the component. The depth of this oxidation is usually maximum by 25 microns (optical microscopy) but today this effect can lead us to real problems when surface characteristics can not stay at a second plane; mainly when there is no after heat treatment procedure, as an example grinding. A case study on it will be seen a bit forward.

The influence on hardness for a shallow decarburization or carbon reduction at components surface is not so sensible by hardness and it is necessary to use metallographic at least to initialize its characterization for HTTP.[2]

The decarburization may be the result of high dew point or low carbon potential level during the diffusion portion of carburize-diffuse cycle, or of prolonged reheating in moist air or other decarburizing gas. The most undesirable effect of surface oxidation is a loss of hardenability.[5]

Remember that in atmosphere carburizing we can minimize the surface decarburization and consequently the internal oxidation and HTTP, but if is mandatory to do not have it, the only way is to proceed the carburizing in a vacuum (low pressure) furnace.

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The base endothermic atmosphere can be done in different ways but the most used ones are generated by endothermic generators and methanol based ones.

Let us see some problems in its equipments that can affect our components, as examples poor carbon and/or excessive carbon offer.

Starting by atmosphere generators sometimes we are faced to problems that seems to be not common due to automatic control as we have today, but even with that it good to point out some issues.

The most common problem is high dew point, this can have some sources, like caused by a leak in the gas cooler, and a repair can solve it. In case of the high dew point is still present , it is possible that the generator is getting more air than indicated on the flow meter; than it is time to have an overview on other air infiltration possibilities as problem at pump shaft, a bad bypass regulator, or loose piping.[6]

Usually if the maintenance procedures are followed no big problems will leave you in bad situation. For the new endothermic generation we are able to get automatic oxygen probe control and pressure and flow rate are automatic regulated making the routine day easier.

Another well spread and good way to generate atmosphere is to crack hydrocarbon inside the furnace. One example is the work with methanol enriching by propane or methane usually and small quantities of dry air to get the carbon potential down. A special care on the other hand must be applied at the way of incoming liquid methanol to the furnace. Up to today one of the best way to work with it, in my experience and view is to pressure the liquid methanol by nitrogen trough vaporization equipment and/or passing trough a pipe with nozzles. There are many variations about the way to go with liquid methanol to the furnace but one in special is going to leave you in troubles soon or late. This is when we just drop the methanol into the furnace, even if you have a plate to minimize the drop size, accumulated carbon can stop the flow without previous advice. If the methanol drop achieves the component under treatment more problems can appear, including surface passivity and points of no diffusion as a result.

Looking both ways, less maintenance will be done at liquid methanol, but the costs can vary around the world.

The metallurgical results as well cycle time are quite similar and just the process variation can lead us to conclude that there is no better than another. The work done by endogas generators and its rate of enriching gas and when necessary air is needed are not so different as well at methanol systems. My particular experience working and comparing it is that we can not say exactly if one or another type is going to reduce or increase the internal oxidation. Comparing both methods the result will not vary more than 02 microns. Another way for atmosphere carburizing generation is the use of ethanol. For sure that the specification can vary and we have to adequate our process to the use of the component, but using ethanol based atmosphere we have to take care about some collateral effects as cementite at grain boundary, excessive soot and higher internal oxidation. This is because the cracking temperature is higher than usual process carburizing temperatures and the carbon level control is the opposite of the others cited here, the control is done adding air continuously to down the carbon potential.

Another common problem for the components and for sure to a safe operation is the air infiltration in atmosphere furnaces.

This can come from radiant tubes broke and/or deterioration, including tube seals, cracked welds, atmosphere fan, leaking cooling chambers and door seal.[7] A good way to detect it is to have a check list including the atmosphere pressure indicator; on the other hand the pressure itself is not conclusive to say that no air infiltration is occurring. Close to the pressure observation is indicated that you measure dew point or if available measure the CO and CO_2 by infrared analysis as example.

Some other points have to be checked to avoid air infiltration as: bearing not properly greased, packing around access plugs, radiant tube plugs or fan plugs has hardened and deteriorated so as not to provide a seal as necessary.

At sequence some case studies will be seen to clear some of aspects involved on the atmosphere issue. The major part of examples are related to endothermic atmospheres but the concept of recirculation, tight, gases distribution and others can be applied wherever atmosphere is present, including decarburizing ones.

3.1 Case Study: Atmosphere Recirculation and Oxygen Probe Location

In a heat treatment shop, a batch furnace line was working for an automobile industry producing parts for assent cars movement/block. The material is based on SAE 8620 H, the case depth is specified by 0, 30 to 0, 50 mm.

The basket/Load is manual assembled and the load was done in a way to have the parts fixed and well distributed to permit a good atmosphere flow at the boost/diffuse stages as well at quenching a good oil heat exchanging. The process was approved and it works for several months without any kind of problem. After a maintenance period it was identified by hardness checking, non-uniformity through the parts carburized and quenched.

It was noted that half of the load/batch has no big differences regarding hardness and other half senseless differences can be identified. See the following sketch, Figure 1.

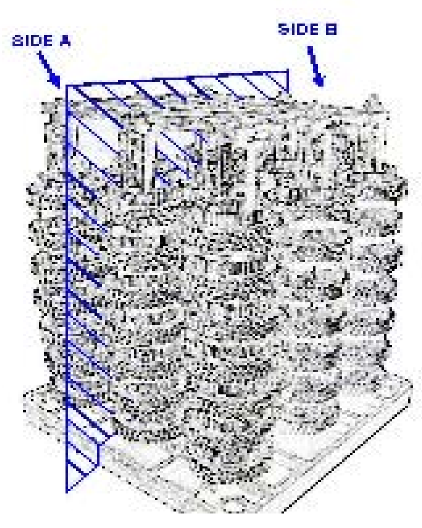

Figure 1. Load sketch.

From the laboratory information came showing that the carbon levels of the parts at left side (side A) were bellow of carbon level specified and checked and analyzed in the beginning of development.

So after the maintenance:

- Half "A" Left side – Parts evaluated were identified with low carbon surface level. The thickness of the case depth found is bellow 0, 10 mm. The surface hardness was varying too much, up to 35 HRA from point to point.
- Half "B" Right side – Parts were evaluated and original specification was achieved, the hardness variation was no more than 10 points by HRA.

Talking the information and historic results, non-uniform carbon diffusion can bee for seen, but the question is, where?

The furnace concept does not include a muffle and recirculation gas was distributed just by the atmosphere recirculation fan. Looking more close to fan blade an indication of changing was noted, this fan has been changed during a maintenance revision and on it the fan blade was changed. The only problem is that the "new" conjunct does not have the proper blade angle from where the correct atmosphere flow comes. The new installed one has not the specified angle due to a mistake specification and than as a result, the atmosphere flow at the load was not achieving the whole batch having its carbon offer during the carburizing and diffusion cycle concentrated on half B.

The proper fan with proper blade fan angle has been installed solving it.

Also the oxygen probe changes its sample gas area measuring position. Before it was installed in one of the furnace side and then for better reading it has been changed to the furnace back, Figure 2 bellow.

Figure 2. New probe location.

3.2 Case Study: Carburizing Atmosphere Evaluation

During an oxygen probe control system installation, the shim stock evaluation was very far away of the probe result readings. The adjustments or corrections at the generated milivolts were done but nonsense was present.

The shim stock evaluation and probe reading use not to be too much different because the CO, CO2 and CH4 for this specific atmosphere (Methanol/Nitrogen based) have been measured by infrared, tested and the algorithm is proved to be OK in this situation.

This customer, an automobile industry has already other 04 systems in batch furnace line working, based on the same atmosphere. As a total of 08 lines under installation, this fifth procedure include cross checking and fine adjustments and at the end of job the results are not stable, the differences looking to the other equipments can not be accepted.

Both shim stock point sample and oxygen probe were located in the same concept and one next to the other. It means an installation located at the middle of the length and at 2/3 of the utile height at most representative area

Such kind of installation and its location have been approved to get optimized results by percentage oxygen probe measurement and shim stock evaluation and comparison.

The results difference between the methods are suppose to be no bigger than 0.05% C and it is widely used in heat treatment shops, but in this case the set point was 1.10%C and real value can not pass 0.40%C even with higher enrichment gas (propane, in this system). The check started but no errors have been detected. The shim stock analysis has a result varying, more because of different enrichment gas flow, but always with results from 0,90 to 1,20.Infrared gas analyst equipment shown CO level by 21%, CO2 by 0,30% and CH4 by 0,75. After electronic and electrical review the weld at the probe connection was tested and a leakage was identified at probe threw close to the furnace wall.

This leakage was fixed and the results got in to the proper way, varying no more than 0, 05%C.

3.3 Case Study: Carburizing Atmosphere Evaluation (Internal Oxidation)

This example is at this item classified due to the usual link to internal oxidation and high temperature transformation products – HTTP.

On the other hand some actions taken are general that can contribute also to reduce the HTTP and are here described as well.

As part of the conventional gas carburizing process “sub-products” take place at materials surface when quenching is done even in a furnace with a sealed quench tank. Those structure results are consequence of an internal oxidation and the goal is to minimize this using some tools reducing atmosphere contamination and getting more effective quenching.

The related case here is an improvement done in a gear DIN 20MnCr5 material in the conventional gas carburizing and oil quenching. The gear in obtained by shaving machining and is important to say that no machining finishing process after heat treatment is held.

The first trials shown as final result a carburizing layer of 0.65 mm in a 0,60 – 0,70mm but HTTP were present in an average of 35 microns. This is not a big problem at all but the part has also as last mechanical operation of shot peening and at this stage about 10 micron of material deformation comes at top of teeth and this can be a “noise” problem when contact other gear. If the HTTP layer is maintained by no more than 25 microns this problem do not come so this is the challenge, maintain a maximum of 25 micron of HTTP.

At beginning the carburizing cycle were carried out at 920°C for carburizing and diffusion by 860°C, quenching is done in a sealed oil tank. Carbon potential is controlled by oxygen probe and set to 1.00%C at carburizing and 0.80%C at diffusion and quenching step.

The quench oil tank has a traditional arrangement like at the follow figure, but without up and down movement . Two agitators guide the oil to the bottom of the tank, where a grid distributes the oil to the load. The agitators have an adjustable speed control.

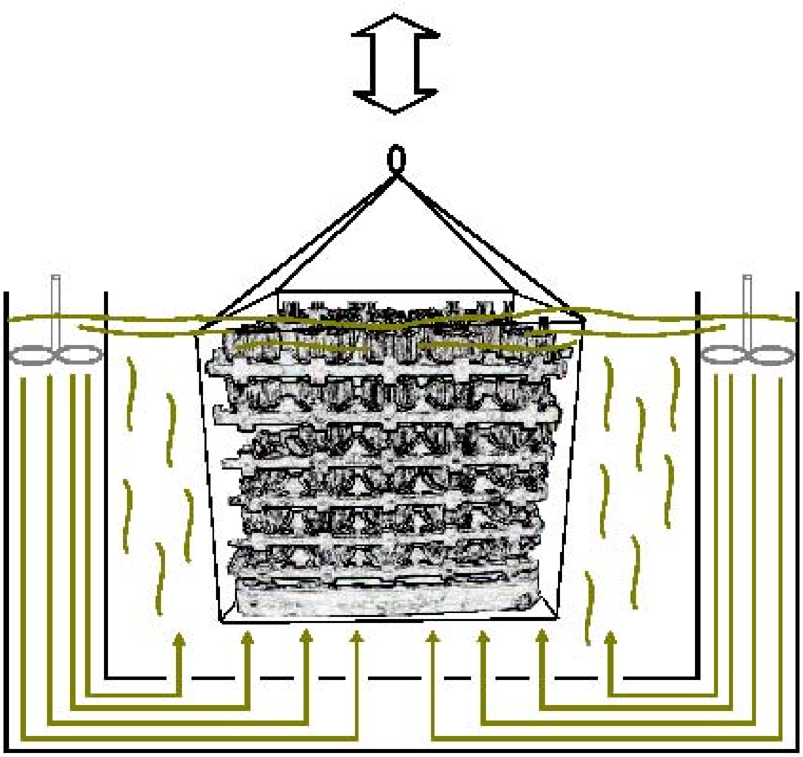

Figure 3. Quench elevator movement.

The heat transfer oil curve of the oil can be classified as a medium range and the oil temperature is maintained from 60° - 80°C.

For the oxidation / HTTP reduction some actions have been taken as follow:

- Vapor stage at quenching

On the samples analyzed it is identified a non-uniform correlation by case depth and HTTP. This was part of the contribution from a not good break on different stage vapor film.

Foreseeing a better uniformity, the oil temperature has been increased from 60°-80°C to 90°- 100°C. This action permits a better oil flow at parts surface. The results are better but not enough to achieve the goal.

At the same line of thinking a quench oil elevator improvement takes place, to achieve a better uniformity, an "up and down" movement has added at quenching elevator system. As soon the load is positioned at the rack and after the load is submerged, a pneumatic piston starts an up and down but maintaining the load submerged.

Now the results had shown a HTTP reduction for a level of 30 micron deep.

Carbon Potential Level / Chemical composition / Faster Quenching Oil Curve / Load density and assembling way and its approaches.

Since our goal was not achieved yet, we came back in order to find some "fine adjustment" in other variables which are not considered before due to some risk involved.

Chemical composition: Another possibility evaluated was to increase the hardenability adding Mo or Cr, in this way we can have better transformation. A test has been carried out but the cost-benefit was not good to go on in this way.

Quench oil: At the quench oil curve, a test has been carried out without success due to the deformation at the gear teeth. When “faster” oil is used, the line measured at gear in the teeth flank goes out of the dimensional limits.

Load density: Reducing number of parts per load / batch, the oxidation / HTTP have also reduced by the level of 26 microns, the border line was not enough and four parts less produced each load done.

Carbon Potential Level and time exposure: Before out of discussion due to the retained austenite present risk in a level not permitted, the manufacturer opens an allowance in a level up to 15%.Close to other points mentioned as example the load density and way of assemble, we were able to increase the carbon potential level to 1,20%C at carburizing and 0,90%C for diffusion. The idea is not just to have higher carbon content at the part surface but to reduce also the time exposed to the temperature minimizing the oxidation. Close to a better washing of the parts that contributes a lot to take the contamination atmosphere out, the final result is that the HTTP level form 20 – 22 microns is achieved and repeated in the normal production series.

3.4 Furnace Burn Out

There are some basic rules that can influence our metallurgical result and not so often they are forgot due to the routine.

Some questions:

Do you have a good procedure for furnace burn out?

Do you know for your process the maximum interval for it?

Do you know the consequences?

Because one company who does not know the consequences and want to produce more and more without stop, they have to spend a lot of money rebuilding the top of a continuous belt type furnace, changing the recirculation fans and paying a heat treatment shop to avoid production stop.

A screw manufacturer has a belt continuous quenching furnace of three zones and open quench tank. Usually it is not a big problem to work continuously because the carbon potential level is not high and burn out of the furnace was restricted to happen twice a year during vacation and maintenance.

The atmosphere was endothermic generated based on propane and air. The enrichment is done by propane as well. Due to the cost reason a synthetic atmosphere have been developed and used. This “new” atmosphere was based in Ethanol and air for diluting, it works for about two months and suddenly the results shown a not repeatability as before, the atmosphere control system gets crazy and decarburizing was present.

The reason, since ethanol has a higher crack temperature, a lot of soot have take place, this soot have stopped the recirculation atmosphere fans, make a passivity on the part surface forcing a not programmed stop.

For sure that this is an example where a atmosphere changing is also present, but it does not mind which kind of process or atmosphere you have, it is always necessary to have a burn out procedure for quality, furnace lifetime and for sure safety.

4 FIXTURES[8]

Varieties of gears of varying weight were carburized in a sealed quench furnace. The base tray used weighed 40 kg and was attached to 60 suspenders weighing a total of 90 kg. In addition, four corner supports and 12 suspender holders were used, bringing the total weight of fixtures to 183 kg. In each cycle, 54 gears were loaded vertically. After a while, it was found that the gears had severe teeth distortions. In addition, the cost and time required to carburize the entire requirement of gears per day was found to be high.

Production was suspended and a study into the problem was commissioned. On further examination, it was found that the fixtures and loading patterns that were being used were adequate for light gears. However, when heavy gears were being loaded along with the light gears, it resulted in the weakening of the suspenders that were holding the gear. The weakening of the suspenders, coupled with the vertical loading of the gears, resulted in them slipping and colliding into each other, thereby causing severe teeth distortions. The loading pattern was changed from vertical to horizontal allowing for a lower center of gravity and therefore more stability. Suspender and holder fixtures were eliminated and instead replaced by fixtures that had three points of contacts with the gears, thereby reducing distortion significantly. The fixtures also ensured that no two gears could touch each other and had a self-lock mechanism. The weight of the base tray was reduced to 36 kg and 10 component support trays were added, weighing a total of 100 kg. The total fixture weight was thus reduced to 136 kg from the earlier 183 kg.

Another issue that we have to keep in mind is about the knick problems that can appear. If a physical contact is present from one to another component, we can have beats that can be a source of a crack in near future.

4.1 General Approach[8]

There are some basic questions and generals rules that can avoid a lot of problems, maintaining the quality specification to the parts and reaching the productivity level to keep heat treatment process competitive.

Following we can have a view of good and really bad examples that unfortunately can happen if your team is not advised or trained to do with.

Talking about fixtures we are saying about assembly load and its influence. Some basic rules must be followed and some features are listed bellow:

- Use fewer fixtures as possible, in this way you are increasing your production rate, promoting a good quenching media flow and for sure saving money.
- Imagine your load assemble with the minimum part fixtures contact and no contact between parts for the same reason as above and in this way you provide a good homogeneity to your part minimizing or avoiding soft points where you want.
- As said earlier, before start your production look in details about things that can result in distortion or bad transformation (examples will be shown).
- It sounds clear, but never forgets to look and check if the load fixture is not going beyond of the furnace limits (internal bricks/doors).
- Remember, the load will suffer some influences really hard (temperatures/movements/cooling up and down), so be sure that it is able to go trough all of processes being firm during it.

Following those basic "rules" you are reducing the risk of to have bad atmosphere / quenching media circulation, achieving a good temperature distribution trough the parts and being confident that metallurgical requests will be achieved in a routine operation Bad conditioned fixtures must be putted away, the pictures (suspender holders) just show the form, imagine the metallurgical structure. Are we able to straightening and continue its use?

5 CONCLUSION

As heat treatment professionals we have to be assertive in to take a proper time for trouble shooting evaluation; often it is better to stop for a while instead of have just the first view and start to change the process. Unfortunately the routine can take us in a narrow view and than we are in dangerous to come in to a vicious cycle that at end leave us to lose our productivity and as well our competitive point to be versatile. Talking about carburizing fails, for sure that a plenty of variables are involved; at this work the sample of cases are not big enough to clarify all issues but if it helps to amplify the view the basic goals is achieved.

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