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Annealing Made Perfect
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SUBJECT - Discussion about cartridge brass

1.0 INTRODUCTION

You have asked us some questions about aspects of brass which are discussed below.

1.1 Cartridge Brass

Traditional cartridge brass is nominally 70% Copper with 30% Zinc added. In the Unified Numbering System (UNS) cartridge brass is grade UNS C26000 in which copper is specified as 68.5-71.5wt%, lead <0.07%, iron <0.05% and zinc the balance. It is noted that cartridge cases are nowadays manufactured from either C26000 or its modifications.

These brass alloy are a single phase alloy, which metallurgically we call "Alpha" phase which has a face centered cubic structure. The solubility of zinc in copper is 32.5% at the solidus temperature of 900°C and 30% at room temperature. At zinc contents above approximately 38% a new phase forms which we call "Beta" phase which has body centered cubic structure. The alpha phase is suited to cold working but not hot working and the beta phase is suited to hot working and not cold working. Brass forgings which are heated to around 750-800°C require some beta phase to allow the hot working. The brasses used in cartridge cases are entirely alpha phase and are ideally suited to cold working having superior ductility of the copper-zinc alloys.

C26000 has a melting point around 915°C and remains as a single phase solid-solution to room temperature.

1.2 Hardness

Hardness can be described as "resistance to indentation" and can be determined in a scientific manner using dedicated hardness testers. Often skilled operators can use workshop techniques such as using resistance to manual filing to work out which material is harder than another however this is only a relative test and in no way scientific.

There are various hardness testing machines such as Rockwell testers which typically use the HRB scale using a 100Kg load on a 1/16" diameter steel ball, Rockwell F or the lighter superficial Rockwell T scale. Brinell hardness testers use a 10mm diameter tungsten ball with test loads of 500Kg to 3000Kg, and Vickers hardness testers use an inverted diamond pyramid with specified dimensions. Upon indentation into the test piece the two diagonals of the diamond indent is measured and averaged and a formula or conversion tables are used to give a hardness in Vickers units HV. Vickers hardness testing is usually divided up into standard Vickers with test loads of 5Kg to 30Kg and microhardness with test loads of 10g to 1Kg. There are other hardness testing units available such as Knoop (HK) which is similar to Vickers except the diamond indenter is elongated. It is noted that Knoop hardness is often favoured by engineers in the USA while Vickers hardness is more favoured by the British colonies.

Each hardness testing method has its uses and limitations. For cartridge cases that are relatively thin-walled it is a requirement that the hardness indent fits onto the brass without deforming the sample under test. For this reason lighter loads and smaller indents offered by Vickers or Knoop microhardness testing are suitable.

1.3 Cartridge Brass Hardness

The hardness of brass has traditionally been discussed in terms relative to its maximum hardness. Publication No.36 by the Copper Development Association (CDA) in the 1960's show that for cartridge brass full hard is typically 175-185HV and fully annealed cartridge brass is typically 65HV. Other publications also describe soft, ¼ hard, ½ hard and spring hard etc.

In the American systems I note that the hardness of cartridge brass is often reported in HRB, HRF and HR30T scales.

1.4 Grain Size

It is not uncommon to hear people talking about hardness and grain size as if they are the same thing. I often hear people discussing how a material is harder because it has a smaller grain. Textbooks on mechanical metallurgy describe how hardness is more related to tensile strength while grain size is more related to yield strength of a material. Equations such as the Hall-Petch formula relate the yield strength to the grain size of a material. Hardness conversion tables occasionally show the tensile strength of a material at a certain hardness. Often the yield strength (hence grain size) will follow the tensile strength – that is as the yield strength increases (grain size reduces) so does the tensile strength increase however this is a generalisation which must be carefully considered.

I have read reference documents that plot tensile strength against grain size in brass and there is a trend in material which has no prior history. Experience however shows that as a material is used and worked and annealed these trends can become very erratic and therefore commentary about grain size and hardness should be treated with caution.

1.5 Annealing

Annealing is a process where a specific amount of heat energy is applied to brass in order to restore the brass back to its soft relaxed state to increase the ductility and/or toughness. Annealing is a function of time and temperature. A brass which has been cold worked previously has some stored energy in it and therefore response to annealing can be quicker and at a lower temperature than an equivalent section size which has not been worked.

Metallurgists discuss annealing as involving recovery, recrystallization and grain growth stages. In the recovery stage hardness remains relatively constant as some of the original properties of the brass recover, during the recrystallization stage the hardness decreases and continues to decrease (although more gradually) during the grain growth stage. If a sample is over annealed than there is a risk of grain growth with a reduction in mechanical properties.

It should be pointed out that references such the ASM speciality handbook on Copper and Copper Alloys describe how the annealing process is a consequence of all the mechanisms operating, which is dependent on the material, processing history and the annealing procedure.

There are many different methods of applying heat in order to anneal a sample. Larger ovens will of course heat the entire cartridge to the annealing temperature which has the potential to soften the side walls and head area to a point that their mechanical properties are reduced. The other scenario is to anneal a very localised area of the cartridge such as the neck area only. The ASM (American Society for Materials) describe how fine grain structures are favoured by fast heating to the annealing temperature and short annealing times.

Flash annealing is the process of quickly heating a small or thin sample to the annealing temperature to minimise heat transfer along the sample.

1.6 Dezincification

Dezincification is a process where zinc is selectively leached out of the brass leaving behind a weaker copper structure. Dezincification occurs under conditions where certain chemical species such as chloride ions, mildly acidic solutions or ammonia-based chemicals attack the brass. Elevated temperatures can accelerate the dezincification process. On a brass sample, fresh dezincification is evident by a pink-coloured structure and with time this turns darker.

I have not seen, experienced or found reference articles that discuss dezincification of brass under heating conditions alone. All avenues point to dezincification in the presence of certain chemicals either on their own or in solutions.

If you have any questions or would like some further assistance in this matter please contact us.

Yours faithfully

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REFERENCES

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