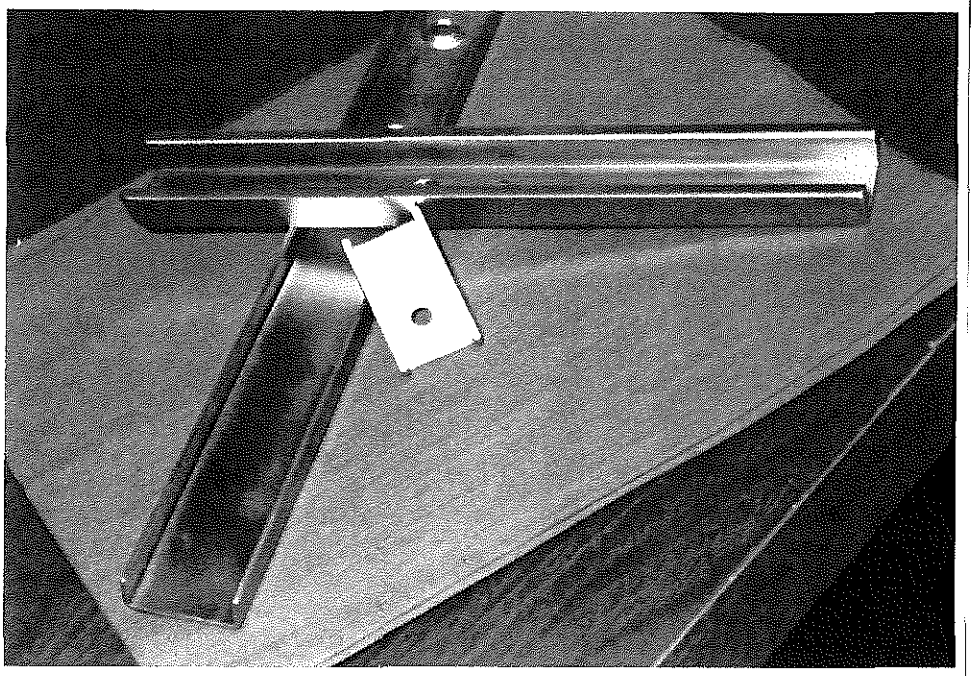
Hydrogen cracking and metal finishing...causes and cures

by Calvin Peck, Quality Engineer

Turning theory into actual working knowledge

Recently, a customer was experiencing base metal cracking after chrome plating. The cracking was almost invisible to the unaided eye, and was only accruing in a bend area on a cold stamped, formed, and machined part. (See accompanying photo of similar part). A lengthy investigation into this problem was launched, examining the customers' base material, heat treating, cold stamping, forming, and machining procedures. The advice of several experts in hydrogen damage and metallurgy was enlisted. At the completion of this investigation it was determined that the hydrogen embrittlement cracking was caused by the stress that was induced into the part during cold stamping, forming and machining before plating. The plating was only acting as a catalyst for the stress that had previously been induced into the base material. It was recommended to the customer to have their base material annealed to reduce the hardness of the material before it was cold worked. This annealing operation solved the problem, eliminated rejected parts for this defect and saved the customer money.



Similar part configurations susceptible to hydrogen embrittlement cracking.

Hydrogen embrittlement has been a problem for metal finishers, design engineers, and metallurgists since the beginning of the industrial revolution. Hydrogen is one of the most widely distributed, lightest and atomically smallest elements. Hydrogen also effects high strength steel the most, but stainless steels, nickel alloys, copper alloys, titanium, and aluminum are also susceptible to the effects of hydrogen. The higher the strength of steel the more susceptible it is to hydrogen embrittlement damage. Metal finishing can be a catalyst for hydrogen stress that has already been induced into a part's processing life cycle. Stress can also enter from casting, forging, grinding and cold working. Often times the hydrogen which has been induced into a part during previous processing operations does not reveal itself as damage until during or after metal finishing, because metal finishing acts as a catalyst for hydrogen stress.

Relieving and minimizing before and during metal finishing

Due to the nature of a plating operation, eliminating the exposure to hydrogen is impossible. But engineering metal finishers can reduce this exposure by taking several effective steps before and during processing. Stress relief baking or shot peening performed before metal finishing can prevent potential hydrogen damage that results from the previous processing operations in the life cycle of a part. Most aircraft specifications call for a stress relief shot peen before plating. These preplating stress relief operations are critical to parts 40 Rockwell C and higher. Cleaning and descaling of the parts prior to plating can be performed by mechanical means instead of hydrogen induced chemical means. During electroplating the best strategy for reducing exposure to hydrogen is to use the highest practical current density for plating. This maximizes plating efficiency and minimizes the generation of hydrogen in the process. Metal finishers can give their customers reliable advice on ways to minimize the hydrogen that is induced into base materials during processing operations before plating.

Hydrogen relieving operations

Metal finishing will always invoke some exposure to hydrogen. A post plating bake operation also eliminates the stress hydrogen acts on in a part, but most importantly, it enables the hydrogen to leave the part, greatly reducing the chances of damage. Most plating process specifications call for parts 40 Rockwell C and higher to be baked for three hours minimum and up to as many as twenty four hours depending on the hardness of the steel. The harder the steel the longer it needs to be baked to eliminate or drive out the hydrogen. The time between the plating operation and the stress relieving bake is vital. Most plating process specifications call for the bake operation to begin within four hours of plating and some of the aircraft specifications require baking to begin within thirty minutes after plating. Although this post plating bake operation increases metal finishing time and cost, it is vital in the prevention of hydrogen embrittlement failure that could potentially cost human lives and be a tremendous financial liability. The cost in extra time and money for this post plating stress relief bake is minimal compared to the potential costs related to a hydrogen failure. Techmetals maintains a number of stress relief, hydrogen embrittlement relief furnaces calibrated and certified with all records on furnaces and bake operations maintained for traceability.

Objective evidence of hydrogen relief

Techmetals takes many steps to assure the reduction of hydrogen embrittlement during metal finishing. The assurance that these specific hydrogen reducing steps are adequate is evaluated on a monthly basis. An experiment was designed and is performed on a monthly schedule. This monthly test consists of plating a specially designed high strength steel notched tensile testing bar. These bars have a special crush roll groove ground into them where hydrogen will concentrate and cause failure. After plating, these test bars are loaded to 75% of their notched ultimate tensile strength and then tensile tested under load for 200 hours. After testing they are examined for cracks and other defects associated with plating. Fracture or cracking during tensile testing designates a hydrogen related failure.