IMOA
INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

PHS – strong, tough and safe

Auto bodies are designed to prevent injuries and save lives when an accident occurs. To protect passengers, while keeping weight to a minimum, requires materials of construction that have both high strength and toughness. Press-hardened steel (PHS) provides these properties and has therefore become the backbone of today's auto body crash structure. As manufacturers push the limits of protection and lightweighting, they are interested in the benefits of molybdenum alloying in this class of steel.

Automotive vehicle crash safety is an extremely important issue and, thanks to its dramatic improvement over the last few decades, accident-related casualties have declined substantially. Even occupants of a tiny compact car struck by a monstrous SUV have good chances of survival today. While crash design must fulfill minimum legal requirements, it is also an important point of consideration for car buyers. To help consumers with their purchasing decision, all cars are rated based on standardized crash-testing procedures, defined and performed by organizations such as the European New Car Assessment Program (NCAP), Germany's Allgemeiner Deutscher Automobil Club (ADAC), the US National Highway Traffic Safety Administration (NHTSA) and others. The best performing cars receive a 5-star rating in these tests, whereas legal standards usually require at least a 3-star rating. Auto makers are torn because designs that increase crash safety tend to add weight to the car body, conflicting with goals of improved fuel economy and reduced CO_2 emissions. Stronger materials that add less weight to the structure allow designers to achieve both objectives.

Critical crash conditions and protective components

The most difficult situation to design for is the side impact crash. The center pillar (the post between front and rear door) is in close proximity to an occupant's pelvis and shoulder, so if a crash causes the center pillar to intrude too far into the passenger compartment, severe injuries are more likely. Therefore, the center pillar and other components in the side structure of the car body should deform as little as possible without breaking. Instead, they must reroute the kinetic energy of the crash to areas of the car body that can safely deform and absorb that energy.

Traditionally, critical components in the vehicle's side structure have been reinforced with one or two extra shells stamped from relatively thick medium-strength steel sheet. However, this adds weight and consumes space needed for airbags and sensors inside the pillar. Using stronger steel would eliminate the need for additional reinforcements, but such steels are difficult to form into the shapes required. To further complicate the problem, there seems to be a "natural law" for steels that says increased strength correlates with decreased formability.

Development of the modern side component

In the early 1980s, the Swedish company Hardtech developed a process that heats a steel sheet to around 900 °C prior to forming it into complex shapes. The cold forming die quickly absorbs the workpiece heat, quenching the formed part. Steel with the right chemical composition transforms during quenching into the extremely strong "martensite" phase, producing a workpiece with very high strength. The process is now known as press-hardening. Although it was well known that alloying steel with molybdenum promotes martensite transformation upon quenching, the original process used a very small alloy addition of boron instead. Accordingly, steel used for press-hardening is also widely known as "boron steel". ›

The side impact crash test reveals the behavior of a vehicle in this type of accident. © Volvo Car Group

Formed parts are heated in the furnace before being press-hardened in the final step. © voestalpine Metal Forming

The Swedish automaker Saab used the first press-hardened components to reinforce the doors of their 9000 model. However, the process was slow to develop because it required more complex, costly and less productive equipment than conventional stamping. It saw only limited use for some time. A breakthrough occurred in 2004 when Volkswagen made major improvements in process efficiency and designed seven press-hardened components for its high-volume Passat model. Press-hardening technology then progressed quickly, and virtually all of today's cars contain press-hardened parts. In 2014, Volvo took the technology to an unprecedented level in its second-generation XC90 SUV model. Nearly 40% of its body structure is made from press-hardened steel, creating a virtually indestructible safety cage around the passengers.

Refining safety and efficiency with the help of molybdenum

During the first 15 years of press-hardening technology the major focus of development was on process efficiency. Now however, material improvement is increasingly important. The original press-hardening steel, known as grade 22MnB5, was not specifically designed for use in car bodies, but could reach a tensile strength of 1500 MPa. For cars, impact resistance, represented by the property called "toughness", is highly relevant. Higher toughness means that the steel can absorb more energy in a crash before failing. Unfortunately, many steels suffer a loss in toughness as strength increases.

As car makers are now interested in increasing the tensile strength of press-hardening steel towards 2000 MPa, in order to further reduce weight, the interaction between strength and toughness has become increasingly important. Projects supported by IMOA have clearly established that molybdenum additions to such steels can provide a good combination of strength and toughness. Molybdenum acts much like a "glue" between the microstructural features within the steel, holding them together under extreme loads. Furthermore, it helps to reduce the deleterious effect of hydrogen, termed hydrogen embrittlement, by limiting its mobility within the material.

Newly developed press-hardening steel grades are already making use of molybdenum in the alloy. The first commercially available 2000 MPa press-hardening steel (34MnB5) contains 0.15 to 0.20% molybdenum. A recently developed 1500 MPa grade (a molybdenum-modified variant of 22MnB5) is intended for thicker sections needed by heavy-truck components. Although it still uses boron, the co-addition of moly boosts its hardenability and permits hardening of the thicker truck sections.

Molybdenum continues to be a part of the future

Experience in this area shows that there are still things to learn about molybdenum's beneficial effects on steel properties. IMOA plays a key role in identifying and promoting these effects in steel applications. The resulting increase in the understanding of how molybdenum benefits users will widen its use. Press-hardened steel in cars and trucks is just one example that shows that molybdenum can even improve existing steel grades. And as demand for lighter and safer cars increases, the demand for molybdenum will most likely increase with it. (Hardy Mohrbacher)