Die materials
for Press hardening of High Strength Steels

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What is Press hardening?

Car body parts are often manufactured through press hardening since it obtains the desired properties of high yield strength and suitable elongation in order to resist mechanical load in a crash situation. These parts are manufactured in large series causing high demands on die material properties to receive a cost effective production.

There are main two types of press hardening processes, direct and indirect. Both process are conducted through forming high strength steels such as 22MnB5 into complex shapes. The blanks are formed in soft condition, which requires less force and reduced risk of springback. Indirect process are performed by forming blanks in cold condition. The formed, trimmed and pierced components are then heated up to austenitization temperature and quenched in the die to obtain strength. Direct is the most common process, the blank is formed in hot condition and quenched in the die. The process has also the biggest problem to solve in terms of tool failure due to the longer heat contact resulting in high die wear [1].

There are several steel grades used as blanks for press hardening but the most common is 22MnB5, commonly for these grades are that they receive their strengths after quenching. The blanks can be coated or un-coated; coated blanks such as aluminum silicon- or zinc based are used to reduce oxide scale formation, protect against corrosion and decarburization. The soft condition material consists of a ferritic- pearlitic microstructure, during the heating process, carbon is dissolved into the matrix and transformation to a new phase Austenite occurs. Austenite is normally not stable at lower temperature and therefore transformed to other phases depending on cooling rate and alloy composition. For high strength steels a fast cooling rate is desired in order to receive the hardest microstructural form, this results also in highest yield and ultimate tensile strength. However, some sections require higher elongation in order to absorb energy. This is achieved by tailored cooling locally, and the cooling rate is lowered to reduce the amount of hard martensite and therefore some amount of the phase bainite is received resulting in soft zone. A tooling setup with both cooled zone dies in order to achieve hard and high strength areas, and hot zone dies to receive soft and ductile areas result in a combining forming process with tailored properties [2].

Failure mechanism on die materials

In order to have a cost effective press hardening production the number of formed blanks needs to be produced with minimum amounts of die sets. This means that that the die material needs to have properties to withstand the potential failure mechanism and thereby receive a suitable die life. Some of the properties needed to meet the requirements is wear resistance, toughness to prevent cracking, temper back resistance to avoid softening due to high heat – minimizing risk for plastic deformation and keep wear resistance. The die material also needs to be have weldability for repair of unplanned maintenance [3].

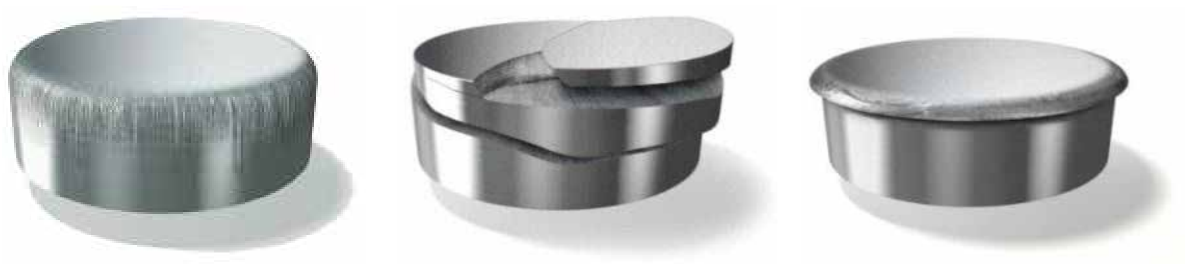

Fig. 1. Illustration of failure mechanism from left abrasive wear, cracking and plastic deformation.

The process method and the selection of blank materials influence the die life in different ways, therefore it is of highest interest to address the selection and performance of tool steel. The use of un-coated blanks results in an oxide scale at elevated temperature on the blanks. This hard oxidized surface layer causes higher abrasion on the tool surface compared to AlSi-coated blanks which don't receive the same abrasive scale. However, in terms of adhesive wear or galling the risk is higher for the usage of coated blanks since the AlSi interacts and sticks on the die [4].

Fig. 2. Shows the wear mechanism on die material, left abrasive and right adhesive.

Material properties are often reliable on the tool steel hardness. However, when the die is in contact with high heat it can temper back and softens. What happens during the softening as a consequence of drop in hardness is that the material loses its strength and therefore it's potential to withstand plastic deformation during mechanical loading. Another negative effect of softening is the reduction in wear resistance.

A material's ability to keep its hardness is dependent on the time and temperature the heat contact is between the die and the blank. Since soft zone dies are used in a section which are heated to elevated temperature, it will be exposed to heat for a constant time and therefore be more responsive to temper back effect.

To extract heat quicker and improve production rate, a high thermal conductivity is desirable, this is normally received as a material property. However, over the last year's trend have shown higher need for thermal conductivity, this has been achieved by moving the placements of cooling channels closer to the surface, see Fig. 3. This results in a better heat transfer but also increases demands on die material due to the increased risk for cracking in the cooling channels. The source for crack initiation could vary from high stress level, - thermal or mechanical but also due to corrosion. The most needed requirement in terms of cracking resistance is high toughness, which is the ability to resist the crack to propagate towards the surface causing water leakage and total interruption.

Fig. 3. Illustration of cooling channel design and placement in Press hardening die.

Tool steel selection

As mentioned earlier there are several potential failure mechanisms that can reduce the potential die life of press hardening dies that needs to be in mind during selection of right die material. The Uddeholm product chart for press hardening, shows several grades for selection to meet the requirements based on abrasive wear resistance and toughness, which is shown in Fig. 4. If cracking is the main problem, Uddeholm Dievar has the highest toughness to resist crack propagation. However, if there is a risk for crack initiated in the cooling channels due to corrosion, Uddeholm Tyrax ESR should be selected since it is a corrosion resistant material with also high abrasive wear resistance. In terms of abrasive wear resistance, Uddeholm Caldie has the highest level and is the steel grade that can receive the highest hardness. In many cases of press hardening, a combination of toughness and abrasive wear resistance are needed where Uddeholm Unimax has universal properties. Uddeholm QRO 90 Supreme has the highest temper back resistance and highest heat conductivity of all grades. This makes the steel extremely suitable for press hardening dies in general but hot zone dies in particular since they are exposed to high heat constantly.

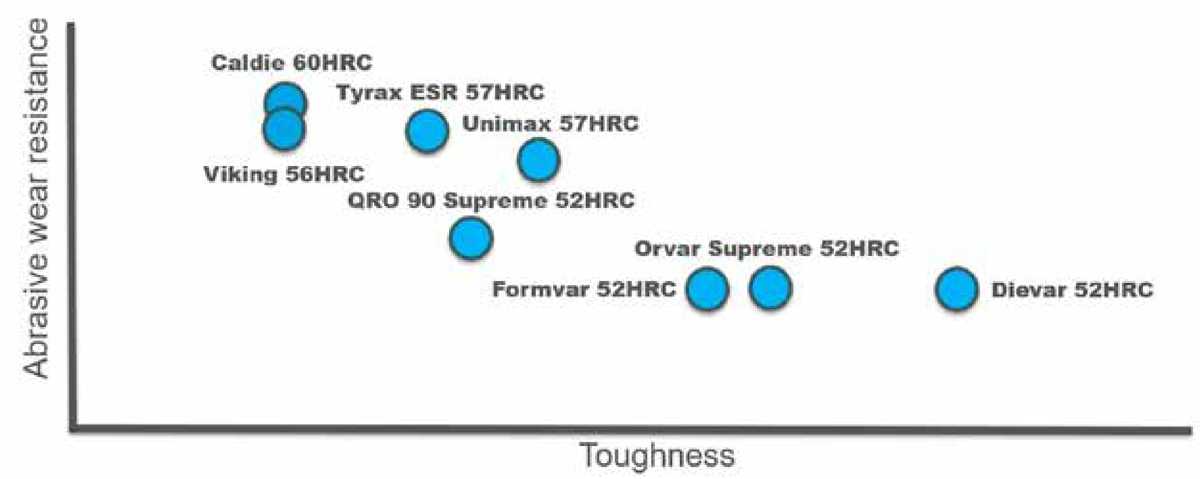

Fig. 4. Product chart for Press hardening die, ranked after abrasive wear resistance and toughness.

Die material requirements for press hardening of high strength blank materials stands out in order for the material to keep its mechanical properties in a consequence of high heat contact. Several failure mechanisms are delayed based on the ability of the die material to withstand against softening, such as strength against plastic deformation and wear resistance. In traditional selection of die material for press hardening, it has been based on mechanical properties before the die material has been in contact with the hot blanks. However, the importance of temper back resistance in order to avoid loss of mechanical properties such as abrasive wear resistance over time. The detrimental requirement in order achieve large series production without interruption is therefore the die materials performance to withstand load and wear during exposer for heat under long time. A die material selection phase is therefore of highest importance to address the desired properties for achievement of long time production.

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