Tool Steel Solutions for In-Die Trimming and Punching of Modern Light Weight Parts Produced via Hot Stamping

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Abstract. The continuous changes of the hot stamping industries demands lead to challenges in the material selection of produced parts and therefore also in the selection of proper tool steels. Improvement of complex lightweight constructions of sheet material puts high demands on the materials themselves and the production processes. The continuing improvement of complex lightweight constructions of sheet material puts high demands on the materials themselves and the production processes. Tool steel still plays a major role when it comes to the issue of tool life enhancement. In addition to thermal stresses, abrasion and adhesive wear are also crucial factors, which influence the material. Considering these aspects, the topic of the hot- and cold punching of 22MnB5 sheet material was analysed in order to evaluate adequate tool steel selections. In addition to the determination of optimum punch geometry and cutting clearance, the abrasive wear behaviour of punches was evaluated via a continuous stroke test. It could be proven that the electro-slag re-melted tool steel BÖHLER K340 ISODUR or the powder metallurgical steel BÖHLER S390 MICROCELAN are suitable for this kind of application and can withstand its high mechanical loads. The implementation of laboratory results in practice is demonstrated by means of industrial application examples. Furthermore, this paper deals with the appropriate selection of high performance tool steels for different types of hot stamping processes and the production of not only manganese and boron alloyed steels, but also aluminium and hybrid parts.

Keywords: Tool steel · Aluminium · Hybrid parts · Hot stamping · In-die trimming · Hot punching · Cold punching

1 Introduction

A high number of car body parts are produced via the hot stamping process. The base material for this application is primarily ultra-high strength steel sheet material [1]. Based on the high thermal stress exposure of the tool, the standard solution for the selection of material is to use hot-work tool steels. However, due to the high demands on the tool material's properties, different types of alloying concepts have to be taken into account. To withstand the harsh wear conditions and high temperatures, which can occur during

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these different processes, high performance tool steels are needed which can reach the required high quality and property levels of the parts. Furthermore, not only the selection for forming but also cutting and blanking of hot stamped parts is of high interest. Investigating the behaviour of the material during the cold and warm punch process is therefore an important method to evaluate the best solution for blanking these kinds of parts. In the following part, the results of these investigations are summarized and discussed. Furthermore, the tool steel selection for Mn and B alloyed steel- and aluminium parts are given. Aluminium is gaining in importance when it comes to substituting heavier steels for structural parts and outer panels [2].

2 Hot- and Cold Punching of 22MnB5

The processing of hot stamped components via punching is state of the art. To improve productivity, it is necessary to include the punch process into the forming process. The next question is, if the hole should be stamped in the hot or hardened and cold condition of the component. Cutting the product via warm cutting puts less stress onto the tool steel. In this case the martensitic transformation during cooling leads to a dimensional change which plays a major role and can therefore not be ignored. However, this solution could lead to high retraction forces. However, after hot stamping the component shows a strength of >1500 MPa which results in high cutting forces. Since only a few empirical values are known in this field, tests were conducted by means of a single-stroke experiment. A continuous-stroke experiment was performed for the cold punching process to determine the wear behaviour of the tools and to conclude the experiments.

2.1 Experimental Setup of the Single Stroke Experiment for the Warm and Cold Punching Process

The single stroke experiments were conducted on a hydraulic press. A modular punching tool was produced including a force/displacement measurement. The measurement technology was integrated and an arrangement of the measuring devices was established. The 22MnB5 strip samples used for the experiment possessed a thickness of 1.5 mm and a zinc coating. After the strips were heated up to austenitizing temperature, they were transferred into the compartment by using tongs. By closing the compartment, a constant transfer time of 16 s was set. After the closing process of the press, the steel strips were punched and removed after a defined holding time. In addition to the force/displacement measurement, the surface of the cut surface was investigated. The parameters rollover, burnish, fracture surface and burr height were determined. The optimal punch geometry and cutting clearance (10% and 15%) for the continuous-stroke experiment were supposed to be received from these experiments. For the single stroke test, the Böhler K340 ISODUR (K340ID) was used as punch material. The bulk material was Böhler K110 (1.2379). Both, punch and die, were hardened and tempered to a hardness level of 58 + 2 HRC.

2.2 Results of the Single Stroke Experiment for Hot and Cold Punching

The following aspects were observed between 10 and 15% cutting clearance during the punch experiments in cold condition:

- With 10% cutting clearance, the rollover is reduced, the burnish is increased.
- The fracture and burr height remain approximately the same.
- A cutting clearance of 15% is recommended to reduce the abrasive wear.

Following assumptions can be made when punching in the warm condition:

- With 10% cutting clearance the rollover, fracture and burr height are reduced while the burnish increases.
- This leads to better results for the cutting clearance of 10%.
- The burr height remains high.

The cutting force during hot punching is significantly lower than during cold punching, whereas the cutting clearance has a minor influence. No significant divergences were discovered when using different punch geometries (flat-, roof- or conical shaped punch). The cutting and retraction forces are hardly reduced. Thus, the flat shaped punch is sufficient, which ensures a cost-effective production of the punch.

2.3 Experimental Setup of the Continuous Stroke Experiment for Cold Punching

A stiff high-speed press was used for the continuous stroke experiments. The active elements were made out of Böhler K340 ISODUR or Böhler S390 MICROCLEAN. The punches were hardened and tempered to a hardness level of 60–62 HRC. The punch head was partially tempered to avoid punch head fraction. The rounding of the cutting edge was set to 100 µm and the cutting clearance to 15%. The punch was repetitively measured after every 10000 strokes. After 50000 strokes, the experiment was stopped. At the end of the experiment, a metallurgical investigation was performed on the punches.

2.4 Results of the Continuous Stroke Experiment for Cold Punching

The wear length of the punch and die was determined by measuring the cutting edge under an angle of 45°. Figure 1 shows the comparison between the wear length of the punches made of the materials Böhler K340 ISODUR and Böhler S390 MICROCLEAN.

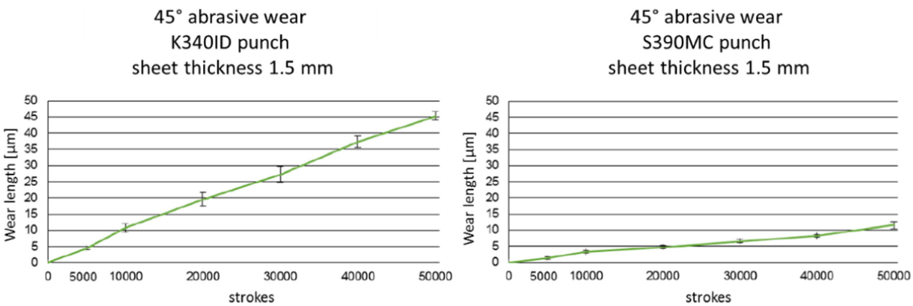

Fig. 1. Results of the continuous stroke experiment.

A nearly linear development of the wear as a function of the stroke rate occurs in both of the tested materials. Furthermore, it became apparent that the higher carbide content of the Böhler S390 MICROCLEAN has a positive effect on the abrasive wear behaviour. Its wear length after 50000 strokes is significantly lower than that of the Böhler K340 ISODUR. The dies show a similar behaviour. In both cases, there was no fracture of the punch or die after 50000 strokes. The lateral surface of the punch made out of Böhler S390 MICROCLEAN shows hardly any abrasive wear damage. The Böhler K340 ISODUR shows a partial plastic deformation on its surface. This leads to the assumption that the stress during the stamping process is high enough to exceed the compressive strength of the material and thus creating plastic deformations. This effect is not as apparent in the case of the Böhler S390 MICROCLEAN. The compressive strength is higher than that of the K340 ISODUR, due to its different alloy and carbide content. This confirms that the use of a high compressive strength tool steel makes sense for hot stamping and allows a long tool lifetime in continuous operations.

3 Tool Steel Selection

A good and efficient way to optimize the hot stamping process is to make the right choices in the tool steel selection. In most cases, the optimum tool steel for hot stamping can only be a best compromise of all these requirements. Standard hot-work tool steels often reach their limits when faced with these demands. The Böhler W302 (H13 type) and W303 (1.2367 type) are conventionally melted hot work tool steels, which can reach hardness levels up to 52 HRC. They have high hot strength, high toughness and very good machinability. These steel grades are used for hot stamping applications without any specific requirements regarding thermal conductivity or abrasive wear resistance. The Böhler K353 is a conventionally melted 8% Chromium cold work tool steel. It is able to reach high hardness levels of up to 62 HRC, which increases the abrasive wear resistance. It is the best solution when a long tool lifetime is required in direct hot stamping. The Böhler W350 ISOBLOC is a specially developed ESR grade. It possesses an excellent through hardenability and is therefore the perfect choice when it comes to big tools and segments with complex geometries. The Böhler W360 ISOBLOC is also a specially developed ESR hot work tool steel. It reaches hardness levels up to 56 HRC. This grade offers an excellent combination of hardness, abrasive wear behavior and good toughness. Furthermore, this material shows the highest thermal conductivity of all the previous mentioned grades. It is perfect for applications with a complex thermal and mechanical loading situation. Due to its high hot hardness level and thermal stability, it is also highly recommended as a soft zone tool steel material for the differential cooling processes. If the customers require strength levels of the sheet material which are especially low, the temperature of the heated segments have to be especially high. Here, the required hot hardness values of cold work or hot work tool steels can exceed their capacities due to the softening behavior of the material. In this case, the tool steel selection could be a high-speed steel like the Böhler S600 or the Böhler S790 MICROCLEAN. These steels can withstand very high application temperatures occurring in the direct hot stamping forming process. These steels can reach high hardness levels between 60 and 66 HRC.

The warm and hot forming of high strength Aluminum alloys does not strain the tools to the same degree as the hot stamping of Mn and B alloyed steels does. The temperature of the actual forming occurs at much lower temperatures. Abrasive wear resistance, high hardness levels and thermal conductivity are not as important in this case. For this application, it is advisable to use the Böhler W300 ISOBLOC. This steel can reach hardness levels of ~52 HRC and combines this with good impact strength and due to its excellent homogeneity and high toughness values.

The tool steel selection for the processing of the aluminum & polymer hybrid components coincides with the solution given for the aluminum sheet process. The application temperatures are very low due to the reinforced polymer and fiber reinforcement itself and the bonding material between the metal and the fiber-reinforced plastic. The tool steel recommendation for the forming and hot stamping of the metal components remains the same as the previous mentioned ones.

4 Summary

The hot- and cold-punching of 22MnB5 sheet material was investigated. In the hot-punching process, it was observed that the proportion of the burnish is considerably higher than in the cold-punching process. Likewise, the cutting forces are significantly lower. With regard to the retraction force, there was no difference between hot- and cold punching. The steels Böhler K340 ISODUR and Böhler S390 MICROCLEAN showed no visible damage (e.g., chipping) after 50000 strokes in the continuous stroke experiments of the cold-punching process. The existing challenge is the process itself. The tool manufacturing process and the periphery has to be designed to withstand high stresses and loads. These investigations have shown that the existing alloy concepts of tool steels and high speed steels lead to good results concerning properties and tool life. An efficient way to optimize the hot stamping process is also the correct tool steel selection. In most cases, this is only a compromise between high thermal conductivity and high abrasive wear resistance. Cold work tool steels (Böhler K353) and hot work tool steels (Böhler W350 ISOBLOC & Böhler W360 ISOBLOC), but also high-speed steels (Böhler S600 & S790 MICROCLEAN) can be used for this application. The processing of Aluminium and hybrid components does not necessarily require high performance tool steels, however in certain cases, an upgrade via tool steel selection can lead to an improvement in the production process.

References

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