Increasing the performance of hot-stamping tools with the new premium tool steel UH1

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Hot-stamping has become a very important technology to produce high-strength automotive body parts. The enormous volume of hot-stamped parts can only be produced efficiently with tools providing reliable performance and long lifetime. The ambitious efforts of the hot-stamping industry to further reduce tool wear and to extend tool life inevitably demands for significantly higher wear resistance of the tool materials. As improved wear resistance cannot be achieved by simply increasing the hardness of the tools Kind&Co developed the new premium tool steel UH1 which provides outstanding wear resistance and simultaneously high toughness. With this development Kind&Co meets the market demands for modern hot-stamping processes. The paper will describe the properties of this new grade as well as results of industrial applications.

Keywords: Hot-stamping; Tool steel; Wear-resistance; Hardness.

1. Introduction

The reduction of emissions has been one of the main topics in the automotive industry in recent years. Stricter emission limits are set by politicians and pose new challenges for car manufacturers. Manufacturers have various options to comply with the new limit values. One of them is to reduce the vehicle weight and thus the fuel consumption. This is possible with the use of high-strength steels: They allow thinner and therefore lighter body parts with the same or even higher crash safety [1]. With the use of these steels, the steel amount in vehicle is decreasing, thus the weight and the fuel consumption. The hot-stamping of high-strength steels has established internationally as manufacturing process. Since the demand for hot-stamped parts is increasing so rapidly, the tools must also increase their performance and lifetime. To further reduce tool wear and to extend tool life inevitably demands for significantly higher wear resistance of the tool materials.

2. Loads on Hot-Stamping Tools

Based on the demand of shorter process cycle time the improvement of thermal conductivity of hot stamping tools was an important topic in recent years. Using tool steels with higher thermal conductivity the quenching period of the process can be reduced in theory [2]. Practically, the reduction of wall thickness between the working surface and the cooling channels proved much more efficient in reducing the time of the quenching process thus cycle time [3]. Therefore the topic thermal conductivity is no longer strongly in focus. As a result of the increased loads of the remaining material between the engraving and the cooling channels the toughness of the tool steel becomes an important property instead. Especially cracks starting from corrosion spots in the cooling channels, has become a factor that limits the lifetime of hot-stamping tools [3]. As none of suitable tool steels for hot-stamping is really corrosion resistant, this topic will not be discussed further here. But an elevated toughness of a steel prevents effectively crack propagation and therefore mitigates this failure risk [4]. The proportion of high-strength steels in vehicles continues to rise. Because of these high production amounts the abrasive wear of the tools steels becomes an even more important topic. A high wear resistance of the tool steel can improve the lifetime tremendously. In addition to high hardness, the utilization of certain alloying elements can improve the lifetime.

In order to achieve the required material properties, the hot-stamping process usually takes place at temperatures above 900 °C. Even though the design of the tools has been improved as described above, the heat load is still enormous, especially on the surface of the tool. A steel with a high tempering resistance can withstand this heat load longer.

3. UH1 – new premium tool steel

In this chapter the new developed premium tool steel UH1 of Kind&Co will be introduced. UH1 is a premium hot-work tool steel. The chemical composition is optimized to follow the demand for higher working hardness while at same time, highest purity and homogeneity allow for a reasonable toughness reserve at high hardness.

The standard solution for hot-stamping applications has long been the steel 1.2344/H13, the chemical composition of which is internationally standardized [5]. As the demands on the tool steels continue to rise, standard steels can no longer meet the requirements for higher hardness and higher wear resistance. Kind&Co anticipated these market demands and developed the steel Cr7V-L a few years ago. The combination of the properties of Cr7V-L is tailored to the requirements of hot-stamping. The successful use in numerous hot-stamping tools by many end users across the world has proven its suitability. With the further increasing requirements Kind&Co developed the premium tool steel UH1. On the basis of the successful alloying concept of Cr7V-L the proportion of carbide-forming alloying elements (C, Cr, Mo, and V) has been further increased to achieve higher hardness and wear resistance. With increasing the chromium content the wear resistance was raised. The UH1 is produced by the Electro-Slag-Remelting (ESR) process which provides several advantages for hot-stamping tools. During the remelting process, the liquid steel passes through a slag bath and is cleaned of impurities. This gives the steel a higher purity than conventionally produced steels and a very homogeneous macro- and microstructure. In addition the alloying elements are distributed more homogeneously which leads to an improved isotropy of the material properties and thus among other things to an increase in toughness. This results, for example, in slower crack propagation, which can significantly delay possible tool failure.

Fig. 1 compares the tempering properties of the three steels 1.2344/H13, Cr7V-L and UH1. With 59 HRC UH1 has the highest secondary hardness of these steels and shows better tempering resistance over the entire working temperature range.

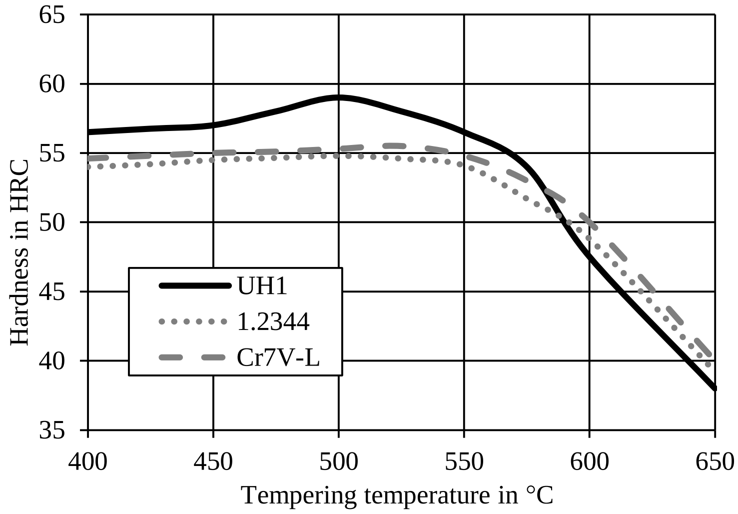

Fig. 1. Tempering curves of the three steel grades

Fig. 2 (a) shows a schematic comparison of the abrasive wear resistance of the three steels. The abrasive wear resistance depends on hardness and carbide content but also on the carbide types and carbide distribution. Even at a lower hardness level UH1 provides a higher wear resistance in comparison to Cr7V-L. With the possibility to use an even higher hardness levels the wear resistance of UH1 increases even more.

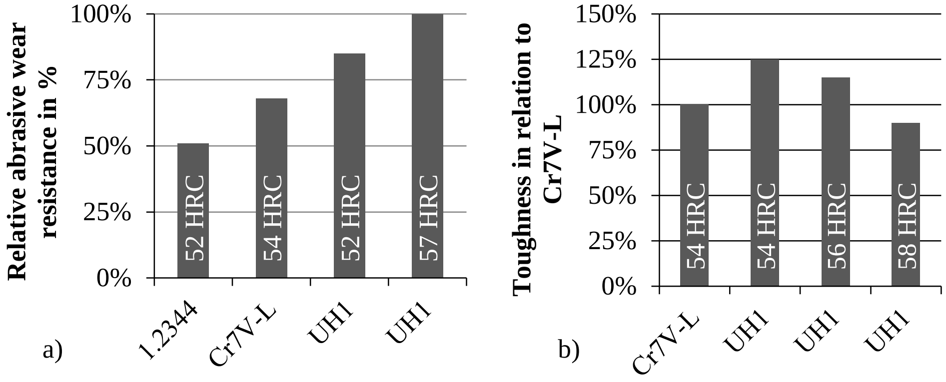

Fig. 2. Schematic comparison of abrasive wear resistance (a) and toughness (b)

In addition to these properties, toughness is, as mentioned above, an important property for tool steels used for hot-stamping. Especially as the distance between the cooling channels and the surface becomes smaller and smaller, a high toughness helps to avoid cracks in this area. In Fig. 2 (b) a schematic comparison of the toughness of UH1 in relation to Cr7V-L is shown. At the same hardness level of 54 HRC UH1 offers a 25 % higher toughness level. Even with hardness of 56 HRC the toughness of UH1 is still 15 % higher.

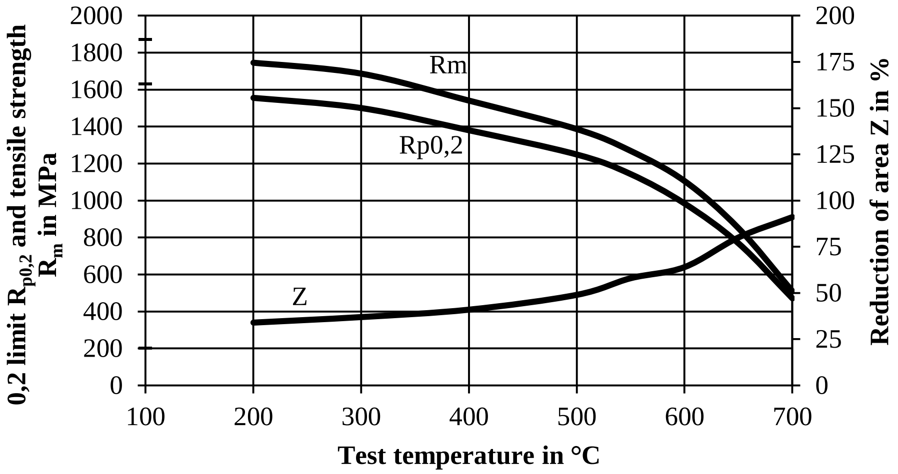

Fig. 3. High-temperature strength graph of premium tool steel UH1

Fig. 3 illustrates the high-temperature strength graph of UH1. The steel develops a very good tensile strength and the curve drops only slightly. The high values of the reduction of area Z reflect the good toughness of UH1. For the heat treatment of UH1 Kind&Co recommends an austenitizing temperature of 1050°C with a holding time of 45min. Subsequent tempering should be carried out at least twice.

Compared to Cr7V-L the development of UH1 has hardly modified the thermal conductivity. Thus the values of thermal conductivity at 400°C are 30.8 W/mK for the Cr7V-L and 29,0 W/mK for the UH1. With respect to that the same thermal behaviour of the tools of UH1 can be expected as in tools of Cr7V-L.

These presented properties show that UH1 will be well positioned to improve tool life, even in comparison to the excellent performance of Cr7V-L.

4. Successful use in industry

Since summer 2019 UH1 has been used successfully in several European companies for hot-stamping tools. At FORD Saarlouis, Germany, UH1 is used for hot-stamping tools in a hot forming line (Schuler PCH Flex applications), which is shown in Fig. 4. For this application UH1 is the only steel which FORD has approved. Before using UH1, it was necessary to remachining the tool by 0.7 mm after 250.000 parts. With UH1 already over 300.000 parts have been produced and a remachining was not necessary until summer 2020.

Fig. 4. UH1 in use at modern Schuler PCH Flex application in a hot forming line of the Ford Company

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Published in:
Advanced High Strength Steel and Press Hardening
Proceedings of the 5th International Conference (ICHSU2020)
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