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Regd. Add.: 101/112, Nyati Millennium, off Nagar Road, Vimannagar, Pune 411014, India
Tel. No. : +91 20 2663 4451/4099; Email ID: secretariat@afm2019.com/info@indianforging.org
Website: www.afm.2019.com/www.indianforging.org

Premium Tool Steel – A Pre-Requisite for Efficient Drop Forging Production

Ingolf Schruff - Kind & Co., Edelstahlwerk, GmbH & Co. KG

Kind & Co., Edelstahlwerk, GmbH & Co. KG
Bielsteiner Str. 124 – 130, D-51766 Wiehl, Germany
Phone: +49 2262 84 498, E-Mail: Ingolf.Schruff@Kind-co.de

Abstract

In the world-wide industrial production of goods the forging industry plays an important role. Being a strategic supplier to the automotive and two-wheeler industry the forging companies have to follow technological changes such as the on-going substitution of forged steel products by forged aluminium products. Metals such as brass or titanium alloys are difficult to forge and expose the forging tools to very high loads during operation. Efficient drop forging processes require productive toolings and thus a careful tool steel selection which respects both the influences of the forging technology and the specific properties of the forged materials. The German tool steel producer Kind & Co., Edelstahlwerk GmbH & Co. KG, produces premium hot-work tool steels suitable for various forging operations. This paper describes recommendations of premium hot-work tool steels for different forging applications distinguishing between hammer and press forging as well as good standard, recommended standard and top brand recommendations.

1. Introduction

India is a fast developing country with rapidly increasing demands in mobility. Indian forging industry is a very important supplier to producers of passenger cars, commercial vehicles, and two-wheelers. In the role as strategic supplier to the automotive industry the forging industry faces many challenges:

- Permanent necessity to improve the profitability of the forging production, along with demands for improved precision of the forgings,
- Automotive light-weight to reduce fuel consumption and toxic emissions,
- Material substitutions, e.g. from steel to aluminium,
- Higher demands towards near-net-shape forging.

Apart from automotive forging applications there is a trend towards more use of titanium and titanium alloys, e.g. in turbine applications for medical implants.

One major key towards improved productivity and profitability is the use of reliable, long-lasting tools. Unexpected tool failure interrupts the forging production and causes additional costs. Abrasive wear is still the main failure mode of forging dies. Controlling wear has therefore direct economic effects on production costs in the forging industry.

Successful precision forging of steel components or forging of materials like aluminium or titanium not only requires carefully adjusted forging parameters like temperature, pressure, and forging rate, it also needs carefully selected tool steels with properties which fulfil the specific requirements of the individual forging process.

Attempts to optimize the efficiency of forging operations by extending the tool life and tool performance can only be successful if they are based on an analysis of the factors influencing the tool life.

2. Factors influencing tool life in forging operations

The performance of a forging tool is the result of a complex interaction of many factors shown in **figure 1**. Quality of the used tool steel is one of them. Other factors respect the forging process as well as the design of the forging dies.

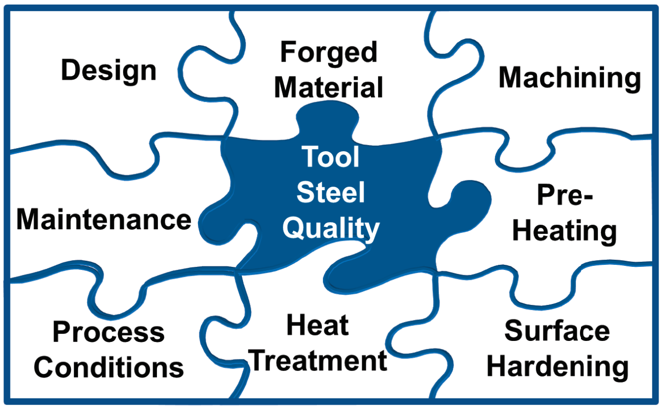

Figure 1: Factors influencing the lifetime and performance of forging tools

The successful selection of premium hot-work tool steel for a long lasting forging tool has to respect these factors as much as possible.

3. Process of tool-steel selection for forging dies

3.1 Influence of the forging equipment

The first aspect to be considered is the forging equipment: forging hammer or forging press. The conditions to which the forging dies are exposed during operation are significantly different. **Table 1** gives a survey of the main stresses on the dies during operation and underlines the different demands for hammer and press forging operations.

	Forging equipment	
	Forging hammer	Forging press
Mechanical load	Extremely sudden	Sudden
Contact time	Short	Medium
Thermal load	Low	High
Main requirement	Toughness	Wear resistance

Table 1: Stresses of the forging tools in different forging applications

Dies for hammer forging dies require mainly excellent toughness, good wear resistance, and tempering resistance. Suitable tool steel grades for hammer forging die s are listed in **Table 2**.

Steel designation		Alloy content in mass-%						
Brand	Mat.-No.	C	Si	Mn	Cr	Mo	Ni	V
PWM	1.2714	0,55	0,30	0,80	1,10	0,50	1,70	0,40
GSF	---	0,28	0,30	0,70	2,80	0,60	1,00	0,40

Table 2: Recommended tool steels for hammer forging dies

The composition of grade PWM corresponds to the internationally standardized hot-work tool steel 1.2714, which is regarded as the standard hot-work tool for hammer forging dies. Grade GSF had been developed by Kind & Co. in order to provide an alternative tool steel with improved tempering resistance and toughness. These two main differences in properties are expressed in **Figure 2.**

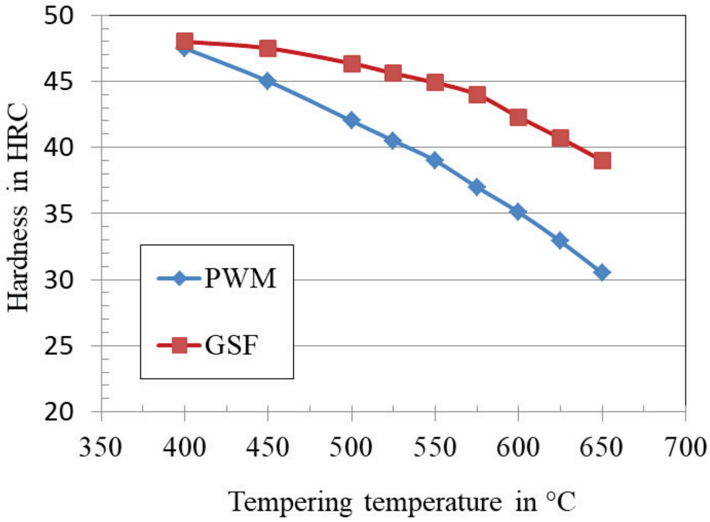

Figure 2: Comparison of the steel grades PWM and GSF Tempering behaviour (left), Impact energy of ISO-V-notch samples, Transverse orientation, measured at room temperature

GSF not only develops a clearly higher tempering resistance, it also develops a higher toughness, even at higher hardness ranges. Due to the low carbon content GSF is easily weldable, e.g. for deposition welding of wear resistant alloys. These facts make GSF a very powerful alternative to standard grades like 1.2714 in hammer forging applications. Kind & Co. therefore recommends GSF for forging dies with a high risk of cracking.

Tool steel grades suitable for press forging dies are listed in **Table 3**.

Steel designation			Alloy content in mass-%								
Brand	Mat.-No.	AISI	C	Si	Mn	Cr	Mo	V	W	Co	Nb
USN	1.2343	H 11	0,37	1,00	0,40	5,20	1,20	0,40	-	-	-
USD	1.2344	H 13	0,40	1,00	0,40	5,20	1,30	1,00	-	-	-
RPU	1.2367	---	0,38	0,40	0,40	5,00	3,00	0,60	-	-	-
CR7V-L	---	---	0,42	0,50	0,40	6,50	1,30	0,80	-	-	-
HP 1	---	---	0,35	0,20	0,30	5,20	1,40	0,55	-	-	+

CS 1	---	---	0,50	0,30	0,40	5,00	1,90	0,55	-	-	+
FTCo	---	---	0,53	0,35	0,40	4,00	2,00	1,00	1,50	0,90	+

Table 3: Chemical compositions of hot-work tool steels for forging presses

The chemical compositions of the grades USN, USD, and RPU are internationally standardized in ISO 4957 Tool Steels. While the alloying concept is standardized, still heat treatment, alloying point within standard bands, forging process etc. are not. Therefore, even "standard" grades from Kind & Co. provide better than average behaviour during operation. Due to their high alloy contents the steels HP 1, CS 1, and FTCo are exclusively made via Electro-Slag-Remelting.

The tempering curves in **Figure 3** demonstrate the individual characteristics of the steels listed above. The diagram points out that the tempering resistance – resistance against softening during operation – increases in this sequence: USN => USD => HP 1 => CR7V-L => RPU => CS 1 => FTCo.

High-temperature strength and abrasive wear resistance are further properties which influence the performance of forging tools (**Figure 4**). Figures 3 and 4 point out that Kind & Co. provides hot-work tool steels which can provide various combinations of properties according to the demands of the customers.

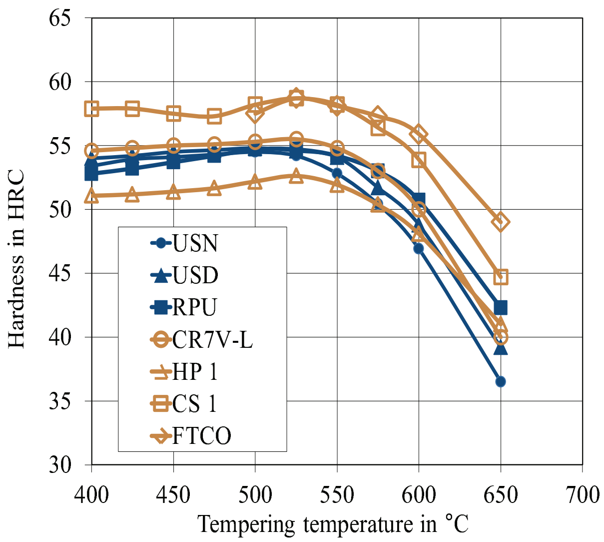

Figure 3: Tempering behaviour of hot-work tool steels listed in Table 3

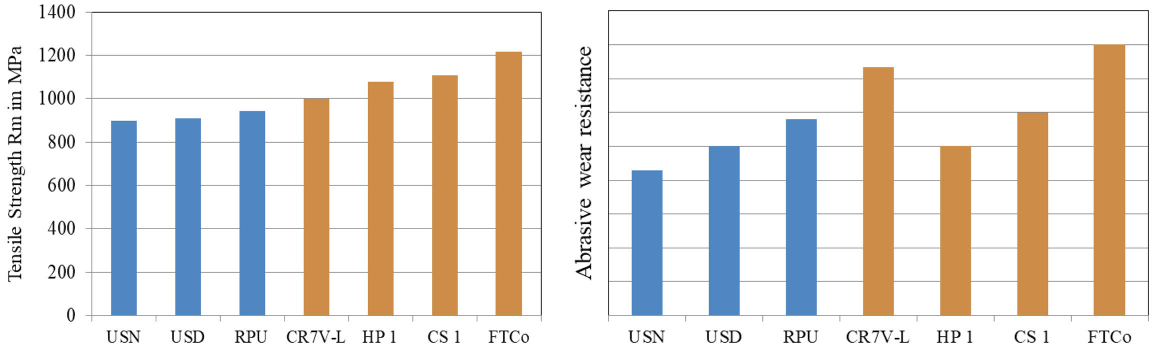

Figure 4: Properties of hot-work tool steels for press forging dies High-temperature strength, measure at 550 °C (left) Abrasive wear resistance (qualitative comparison; right)

3.2 Steel Selection for Press Forging Dies

The steel selection for press forging dies distinguishes between hot and warm forging as well as high-speed forming. Another aspect to be respected is the forging material: Steel, aluminium, copper or brass or even titanium. Each of these metals has an individual deformation behaviour and range of forging temperatures and these factors are important in the selection of suitable tool steels.

3.2.1 Tool Steel Recommendations for Hot-Forging of Steel

Tools for hot-forging of steel under forging presses are exposed to high thermal loads and intensive abrasive wear. The tool steel selection should respect whether the dies are used as a blocker (first, rough stage of deformation) or as a finisher (final step of deformation).

Blockers are exposed to higher thermal and abrasive loads than finishers so that the hardness level of blockers should be higher than that of finishers.

RPU with a hardness of 42 – 46 HRC can serve as a good tool material for standard applications in blockers. As grade CR7V-L provides a higher carbide content this hot-work tool steel with the same hardness range is recommended for dies with higher wear resistance. In case that high wear resistance and improved toughness are required (deep cavities) the special grade CS 1 with a hardness range of 44 – 48 HRC can offer former improvement of the forging die performance. In case of flat cavities the hardness range of these three steel grades can be raised by approx. 4 HRC.

The thermal and abrasive loads in finishers are lower than in blockers. Kind & Co. recommends the same steel grades as for blockers. For deep cavities RPU and CR7V-L can be used both having a hardness of 40 – 44 HRC, in case of the tougher grade CS 1 the hardness can be raised to 44 – 48 HRC. In case of flat die cavities an increase of the hardness by 4 HRC can be considered.

In the production of crankshafts the special hot-work tool steel CR7V-L has successfully replaced steel grades like 1.2343 (AISI H 11) and 1.2344 (AISI H 13) and has increased the tool performance significantly (**Figure 5**).

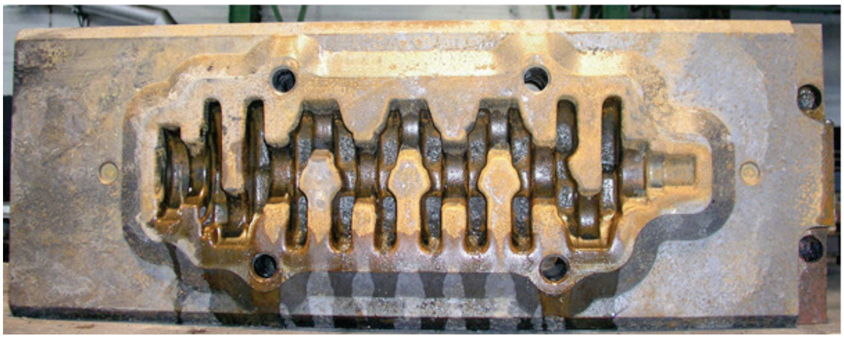

Figure 5: Forging die for a crankshaft made of hot-work tool steel CR7V-L
CR7V-L: 45 HRC; H 11 and H 13: 45 HRC; Increase of production: 60 %

3.2.2 Tool Steel Recommendations for Warm-Forging of Steel

This forging process in the temperature range between 650 and 900 °C is characterized by complex geometries and high precision of the forgings. The dies are exposed to high abrasive wear and to thermal fatigue. Recommended hot-work tool steels therefore need to have high carbide content in order to provide abrasive wear resistance and good high-temperature strength to prevent cracks. RPU with a hardness of 48 – 53 HRC can be regarded as standard tool steel for this technology. Highest requirements in wear resistance, e.g. for top dies, can be fulfilled by the grade FTCo with a hardness of 53 – 57 HRC. As bottom dies often need a higher toughness CS 1 (52 – 56 HRC) should be selected instead of FTCo for highest requirements.

3.2.3 Tool Steels for High Speed Forging

Tools for this technology produce rotationally symmetric components with a very high frequency. Being exposed to extreme water cooling tools fail mainly due to abrasive wear.
Dies need to have a combination of toughness and wear resistance so that USD with a hardness of 50 – 54 HRC can be regarded as a good standard tool material. RPU (50 – 54 HRC) achieves a higher wear resistance and better performance. Highest performance can be achieved using CS 1 as the high toughness of this grade allows increasing the hardness up to 53 – 57 HRC for highest performance.
USD and RPU can also be used for high-speed forging punches. The high carbide content of FTCo (53 – 57 HRC) provides the very high wear resistance and the high performance of punches.

3.2.4 Tool Steels for Aluminium Forging

Aluminium gains more and more importance in weight reduction of passenger cars, commercial vehicles and aeronautic applications. More and more forged aluminium components replace forged steel components in the chassis of modern cars. Depending on the composition of the aluminium alloy the forging temperature is in the range of 300 and 550 °C, the contact time between forging and die is longer than in steel. Aluminium forging is characterized by