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**REGULAR ARTICLE**

# Improvement by Heat Treatment of the Mechanical Properties of a Grooving Cutter

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Our work entitled improvement of the mechanical properties of a Z80WCV 18-04-01 high-speed steel grooving cutter (three sizes) by heat treatment, the latter can play an essential role in improving the mechanical and structural properties of grooving mills. The results obtained showed that the heat treatments allow to obtain a favorable microstructure, with a martensitic phase formation and a homogeneous distribution of carbides. These structural changes have led to an increase in the hardness, strength and durability of the milling cutters to be grooved in addition, it has been observed that the application of cumulative revenues has a significant impact on the mechanical and structural properties. The successive revenues favored the transformation of quenching martensite into tempering martensite and the elimination of residual austenite, leading to a gradual increase in hardness and wear resistance.

**Keywords**: Grooving cutter, Heat treatment, Martensitic phase, Carbides, Residual austenite, Hardness.

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## 1. INTRODUCTION

The cost of tools is often an important part of the cost of manufacturing products. In many cases, a significant reduction in the unit cost of the tools resulting from an increase in their lifetime of several tens ofhundred is possible and easy to achieve if attention is paid to the choice of steel grade as well as its heat and surface treatment [1]. There are currently a large number of grades of tool steels, despite the simplification made with the implementation of the new standards, which can make this choice difficult for the user, This is all the more so since the conditions under which tool steels are used meet particular criteria. 600 to 650°C at a higher degree than other steels [2].

High-speed steel grooving mills are essential tools in the machining industry [3]. They are widely used for making precise and high quality grooves in different materials [4]. However, wear and deterioration of grooving mills can reduce their effectiveness and service life [5]. To overcome these problems, heat treatment is a commonly used technique to improve the mechanical properties of high-speed steel cutting tools

For the cutting edge of machine tools, the following materials are used, classified into six groups in order of increasing hardness: fast steels, carbides, ceramics, cermets, diamonds and polycrystalline cubic boron nitride [6].

Before discussing the materials constituting the cutting part of the tools, recall that certain structural steels are often used, for reasons of economy, to make the non-cutting part of the tools: drill bits or reamers shanks, tool bodies, etc [7].

The choice of a material for cutting tools depends essentially on its chemical composition and the conditions of its elaboration, in particular its mechanical properties. [8]. Heat treatments give it significant changes in its own structure. Heat treatments are intended to give the milling cutter the most suitable mechanical properties for its implementation and use [9]. In general, heat treatments do not modify the chemical composition but make changes from the point of view of constitution (carbon state, allotropic form), structure (grain size, component distribution) and stress state. A heat treatment must include: a heater; maintenance for a time at the treatment temperature; cooling (return to room temperature) [10].

## 2. EXPIREMENTAL PROCEDURE

Our experimental study was carried out at the Mechanical Constructions Establishment of Khenchela – Algeria, it consists of a structural and mechanical characterization of the steel studied. We will begin by presenting the specific material grade used for the manufacturing of the three-size grooving cutter, highlighting its key properties. We will also explore the heat treatment applied to the milling cutter, as well as the structural and mechanical characterization techniques used, including sample preparation and equipment used.

The milling cutter (Fig. 1). We are studying consists of two distinct parts: the active part, made of high-speed steel Z80WCV 18-04-01, and the tail, made of ordinary steel *C*45 [10]. The table below shows (Table 1) the chemical nuances and compositions of these two materials. The chemical composition was determined by the spectrometer.

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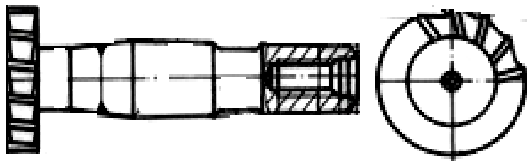

**Fig. 1** – Three-size milling cutter

**Table 1** – Chemical composition of study steels

| **Z80WCV 18-04-01** | **% Mass** |
|---|---|
| C | 0.79 |
| W | 17.12 |
| Cr | 3.69 |
| V | 1.1 |
| Si | 0.39 |
| Mn | 0.19 |
| Fe | 75.39 |

| ***C45*** | **% Mass** |
|---|---|
| C | 0.79 |
| W | 17.12 |
| Cr | 3.69 |
| V | 1.1 |
| Si | 0.39 |
| Mn | 0.19 |
| Fe | 75.39 |

We carried out a heat treatment on a set of five milling cuter tool. The process began with preheating to 860°C in a salt bath for 5 minutes, followed by subsequent heating to 1250°C in the salt bath for 1 minute. Then the milling cuter tool were soaked in nitrates heated to 260°C for 5 minutes, before being air-cooled as shown in (Fig. 2) [11].

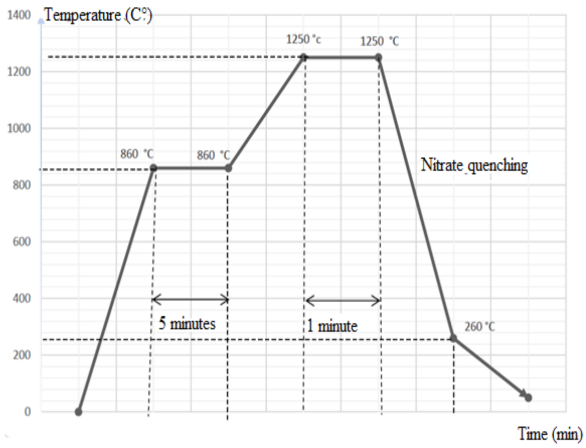


**Fig. 2** – Quenching cycle

**Table 2** – The revenue figures for each milling cuter tool

| **Milling cuter tools** | **Number of revenues** |
|---|---|
| milling cuter tool 1 | (quenching only) 0 |
| milling cuter tool 2 | 1 |
| milling cuter tool 3 | 2 |
| milling cuter tool 4 | 3 |
| milling cuter tool 5 | 4 |

Subsequently, each milling cuter tool has undergone a specific number of tempering, the details of which are presented in the (Table 2) below.

Structural characterization generally involves the preparation of samples, including cutting, polishing and chemical etching, in order to reveal the different phases and characteristics of the microstructure by an optical microscope.

Polishing the sample consists of making its surface smooth and shiny, avoiding any scratches that could hinder further examination. It is usually divided into two stages: grinding and finishing polishing.

The polishing machine equipped with a disc and a continuous watering system is used [12].

## 3. RESULTS AND DISCUSSION

The objective of this part is to analyze the effect of heat treatment on the mechanical properties and microstructure of high-speed steels (Z80WCV 18-04-01).

Our study aims to understand the structural changes and the mechanical characteristics of this steel following the heat treatment. We will also try to explain and interpret the results obtained in order to obtain a better understanding of the studied phenomenon

We conducted an analysis of our material prior to heat treatments, namely the base steel

In this study, we based our analysis on the number of revenues made on the samples. Each sample was subjected to a specific number of income. By modifying the number of revenues, we seek to evaluate the impact of this heat treatment on the mechanical properties and microstructure of hight seep steel (Z80WCV 18-04-01).

The (Fig. 3) represents the structure of our steel has the basic state without having any treatment, of a globular perlite structure in addition to a quantity of primary carbides ($Cr_7C_3$) of more or less rounded

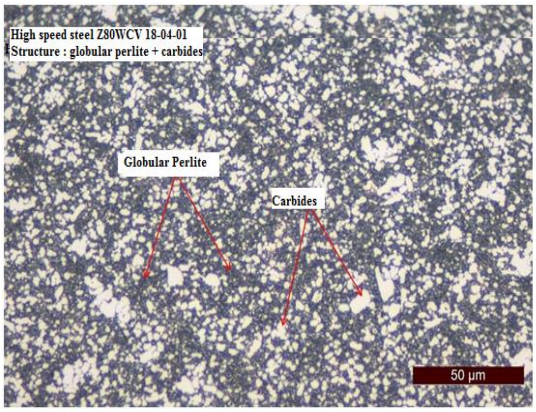


**Fig. 3** – Microstructure of steel in the basic state

In this section, we began the heat treatment process, followed by the first tempering

In this part of the study, we applied a specific heat treatment to the samples. The process included preheating at 680°C for 5 minutes, followed by heating at 1250°C for 1 minute, then quenching in a nitrate bath at 260°C for 5 minutes, and finally cooling with air.

Microscopic observation of the treated samples allowed to identify the structural changes. In particular, we observed the formation of quenching martensite, which is a hardened metal structure resulting from quenching. In addition, residual austenite was detected, indicating the presence of an unprocessed phase during the cooling process. In addition, primary carbides were also observed.

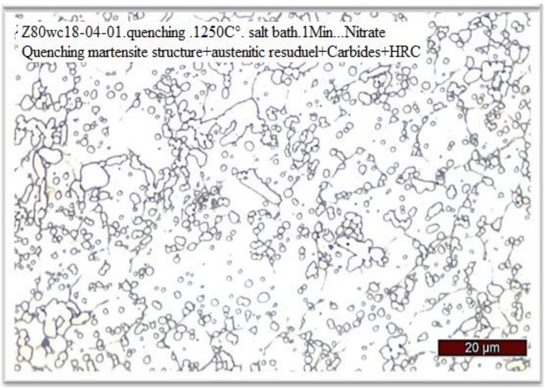


**Fig. 4** – Microstructure of steel after quenching

This microscopic analysis provided crucial information on the structural transformations induced by heat treatment. The presence of quenching martensite and residual austenite can significantly influence the mechanical properties of the studied higt speed steel. In addition, the identification of primary carbides is essential to understand the phase distribution and interaction in steel (Fig. 4).

We show you the microstructure after tempering a first income at 600°C for 2 hours, the results of this characterization revealed several significant observations. First, we found the formation of income martensite. Tempering martensite is a metal structure that is formed during tempering.

In addition to tempering martensite, we also observed the continuous presence of quenching martensite, residual austenite and tungsten carbides (WC) in the structure (Fig. 5). The uniform distribution of carbides in the structure is particularly interesting, as it can contribute to strengthening the fast steel and improving its mechanical properties.

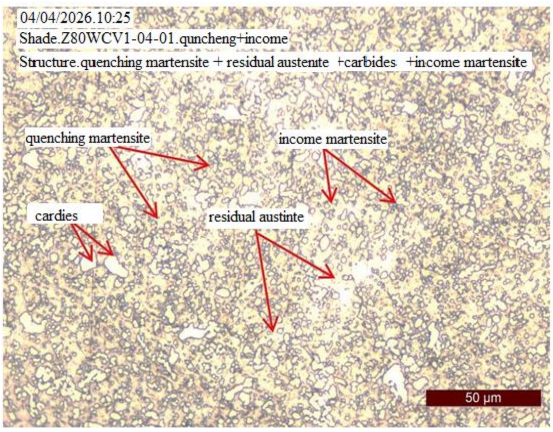


**Fig. 5** – Mocrustructure of steel after the first income

The identification of these different phases in the structure after the first tempering allows us to better understand the transformation mechanisms and microstructural evolutions that occur during heat treatment. These results provide valuable insight into the expected mechanical properties of high-speed steel, particularly in terms of wear resistance and hardness.

After performing a second tempering under the same conditions as the first (600°C for 2 hours), we observed additional changes in the structure of the high-speed steel (Fig. 6).

An important observation is the increase in the amount of tempering martensite compared to quenching martensite. This indicates that the second tempering has further promoted the formation of tempering martensite, which can lead to an improvement in mechanical properties.In addition, we found that residual austenite and tungsten carbides (WC) were still present in the structure after the second income. Residual austenite may result from incomplete transformation of the initial phase during heat treatment, while tungsten carbides (WC) retain their distribution in the structure.

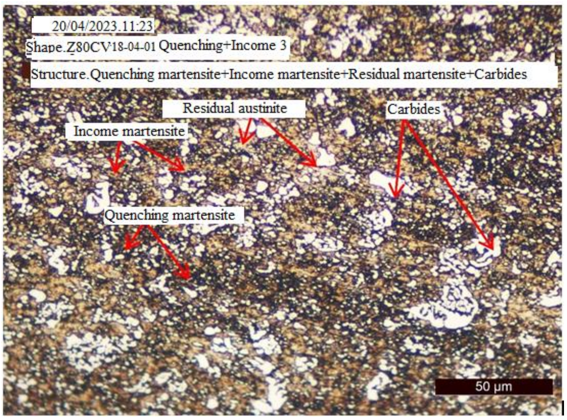


**Fig. 6** – Mocrustructure of steel after the second income

After making a third income, microscopic observation revealed a significant decrease in the amount of quenching martensite compared to previous incomes. On the other hand, the income martensite increased considerably and took a prominent place in the structure. Tempering martensite developed to the point of becoming a dominant matrix.In addition, we observed that residual austenite and carbides (WC) were still present in large quantities in the structure after the third tempering (Fig. 7).

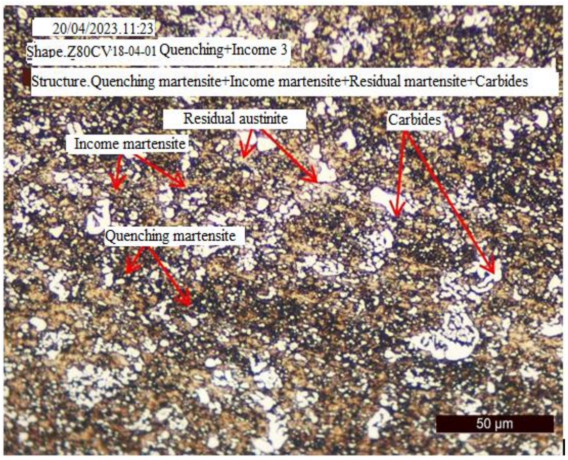


**Fig. 7** – Mocrustructure of steel after the third income

This observation shows that each subsequent tempering leads to a transformation of the quenching martensite into tempering martensite. The initial quenching martensite undergoes a change in its structure and gradually transforms into tempering martensite, which becomes the main structural phase. This transformation process from quenching martensite to tempering martensite can be influenced by several factors, such as the diffusion of alloying elements and the restructuring of atoms in the crystal structure.After performing a fourth tempering at 600°C for 2 hours, a structural observation revealed the presence of a mainly martensitic structure, consisting of tempering martensite and tungsten carbides (WC).

These results clearly indicate that the other phases present in the initial structure underwent a transformation and transformed into tempering martensite. Tempering martensite became the dominant phase in the structure of fast steel after several successive tempering.

This transformation can lead to significant changes in the mechanical properties of high-speed steel, as tempering martensite may exhibit better strength and hardness compared to the initial phases.

**Table 3** – Sample HRC hardness values structure.

| Sample | State | HRC Hardness |
|---|---|---|
| 1 | 0 Income (quenching only) | 59 |
| 2 | 1 Income | 60 |
| 3 | 2 Income | 63 |
| 4 | 3 Income | 64 |
| 5 | 4 Income | 65 |

After the second tempering it is found that the presence of WC carbides is more important in the Table 3.

During the third and fourth tempering (Fig.8) these carbides reach a maximum quantity this results in a secondary hardening. These carbides then play an essential role in the reinforcement of fast steel and the improvement of its wear resistance and increase in hardness. The cumulative tempering affects the hardness and structure of our high-speed steel tool, the influence of the number of revenues on the microstructure of the fast steel studied is clearly highlighted by the observations made.

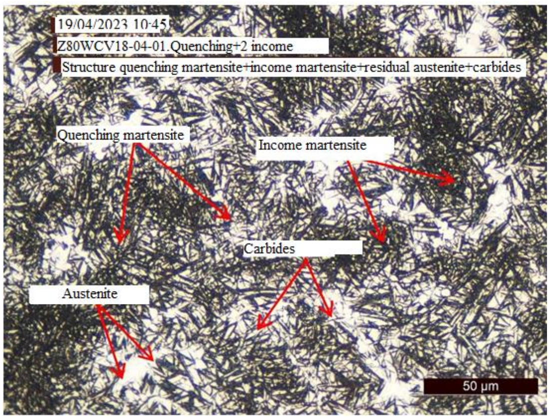


**Fig. 8** – Mocrustructure of steel after the fourth income

Each time the number of incomes increases, we observe a progressive transformation of the quenching martensite into tempering martensite. Tempering martensite is becoming increasingly dominant in the structure of high-speed steel, in addition to the other initial phases.

In addition, residual austenite and tungsten carbides (WC) present in the structure after each tempering, retaining their initial distribution. This shows that these phases are less sensitive to the transformations made by incomes and maintain their stability [13].

This structural evolution of fast steel with the number of revenues has significant consequences on its mechanical properties. The presence of tempering martensite is generally associated with improved strength and toughness, which strengthens the steel and makes it more resistant to stress and wear. However, the transformation of other phases into tempering martensite can also influence other properties, such as hardness.

The following table shows the variation in hardness after tempering and also the hardness before tempering Table 3 shows the hardness values of the samples before and after heat treatment.

The variation of the HRC hardness of our high-speed steel (Z80WCV18-04-01) according to the number of tempers applied. The results indicate an increase in hardness after each income. This resulted in a significant increase in HRC hardness, reaching a satisfactory value (HRC = 65).

The sample without income had the lowest hardness value (HRC = 59). Thereafter, the hardness values increase proportionally to the number of incomes applied. These results highlight the remarkable impact of the number of revenues on the hardness of our high-speed steel. In summary, our observations indicate that each applied tempering leads to an increase in the HRC hardness of fast steel. The fourth tempering particularly played a major role in obtaining a martensitic structure with carbides (WC), resulting in high hardness. These results highlight the importance of the number of revenues in the improvement of the mechanical properties of our high-speed steel.

## 4. CONCLUSION

In conclusion, the application of cumulative revenues has led to a favorable structural transformation in high-speed steel, improving its hardness and wear resistance. This demonstrates the importance of heat treatment and the number of revenues in optimizing the mechanical properties and performance of high-speed steel.

These results have practical implications for the use of high-speed steel in applications requiring high strength and durability, especially in machining operations.

It opens new perspectives for the optimization of the properties of high-speed steel grooving mills, highlighting the importance of heat treatments and cumulative revenues. It is recommended to continue this research by exploring other heat treatment techniques and studying the impact of specific machining conditions in order to better understand and exploit the potential of high-speed steel grooving mills in various applications industrial.

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## Поліпшення шляхом термічної обробки механічних властивостей матеріала фрези


B. Chermime[1,2], K. Mansouri[2], H. Djebaili[1], H. Hadjela[1], O.A. Abbassi[1], O. Hamidane[1]

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Дана робота спрямована на поліпшення механічних властивостей Z80WCV 18-04-01 високошвидкісної сталевої фрези шляхом термічної обробки, останній може відігравати важливу роль у поліпшенні механічних та структурних властивостей матеріалів . Отримані результати показали, що термічна обробка дозволяє отримати сприятливу мікроструктуру, з мартенситним утворенням фаз і однорідним розподілом карбідів. Ці структурні зміни призвели до збільшення твердості, міцності та довговічності фрез.



**Ключові слова**: Грохозний різак, Термічна обробка, Мартенситна фаза, Карбіди, Залишковий аустеніт, Твердість.