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THE EFFECT OF CRYOGENIC TREATMENT ON THE INCREASE OF PROPERTIES OF A PLASTIC MOULD STEEL

Gábor KŐRÖSI[1], László TÓTH[1]

[1] Material Science Department, Bánki Donát Faculty of Mechanical and Safety Engineering, Óbuda University, 8. Népszínház Str.; 1081, Budapest, Hungary

Abstract

The article presents experiments aimed at increasing the properties of a plastic mould tool steel with a special heat treatment technology called shallow cryogenic treatment. Our chosen steel grade was Böhler M340 ISOPLAST. We would like to show how cryogenic treatment affects the wear and corrosion properties of this particular steel grade. We can conclude with tests and calculations that the cryogenically treated specimen showed at least 40% better wear and corrosion resistance properties, then the one treated with conventional heat treatment. Based on these findings, we expect that the tool life will also be longer using this heat treatment technology.

Keywords: *plastic mould steel, cryogenic treatment, wear resistance, corrosion resistance.*

Introduction

The processing of commodity plastics has become extremely important in recent decades, this is mostly due to the automotive industry [1]. For this reason, the recycling of used plastic parts has become a priority. Especially in the case of materials like PVC, which cannot decompose in nature. The tools used during these processes are exposed to heavy wear and corrosion.

Fig. 1. Corroded tool, used during recycling of PVC

Heat treatment can improve properties of metals and this improvement can be significant, for example, in the case of titanium alloys [2].

Cryogenic treatment is an add-on process, which goal is the above-mentioned improvement of the properties of metals after or during heat treatment [3]. There are a few types of sub-zero temperature treatment [4]. We are focusing on shallow cryogenic treatment, which

*Corresponding author: toth.laszlo@bgk.uni-obuda.hu

means a cold treatment between temperatures of -80 °C and -150 °C, after quenching [5]. Several recent studies have shown that cryogenic treatment can improve the mechanical properties of cutting tool steels [6], so those can meet the requirements of the machining industry [7].

With this study we want to investigate how a tool steel material - that was developed with the specifics of plastic processing in mind - behaves under conditions such as abrasive wear and corrosion.

Material, Methods and Experiments

The steel grade we used in our experiments is the Böhler M340 ISOPLAST [8]. It is a plastic mould tool steel, with a chemical composition that can be seen in Table 1., which was determined with a Hitachi PMI MP2 spectrometer, made in Japan. The ISOPLAST designation in the name denotes a material, that was purified by electroslag remelting process (ESR). It helps to create a clean, refined alloy, with a chemical homogeneity.

Table 1. Böhler M340 chemical composition, measured with a spectrometer (wt. %)

C	Cr	Mo	Si	Mn	V	Fe
0.53	17.20	1.11	0.44	0.41	0.10	balance

Our chosen material was heat treated in two different ways in a Schmetz IU72 type vacuum furnace, made in Germany. One specimen was quenched, then three times tempered (Fig. 2.). The other specimen went under a shallow cryogenic treatment between the quenching and tempering processes (Fig. 3).

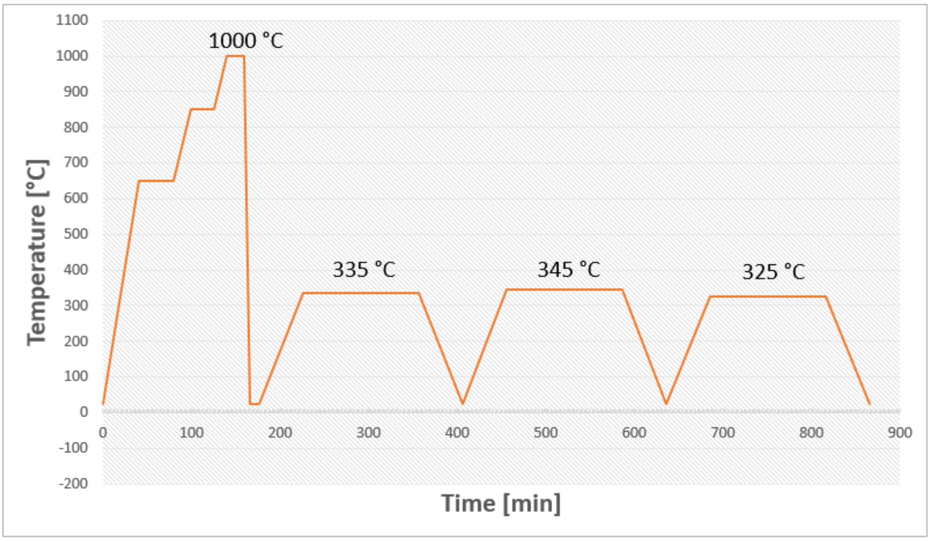

Fig. 2. Heat treatment diagram of the conventionally treated specimen

After the heat treatments, we conducted hardness, wear, and corrosion resistance tests, using samples made from both specimens with EDM wire cutting technology [9].

The raw material is annealed in the delivery state. The hardness of each sample was determined with an Ernst AT130 D type universal hardness tester, made in Switzerland. Used equipment: Brinell: hardened steel ball, Rockwell C: cone-shaped diamond indenter.

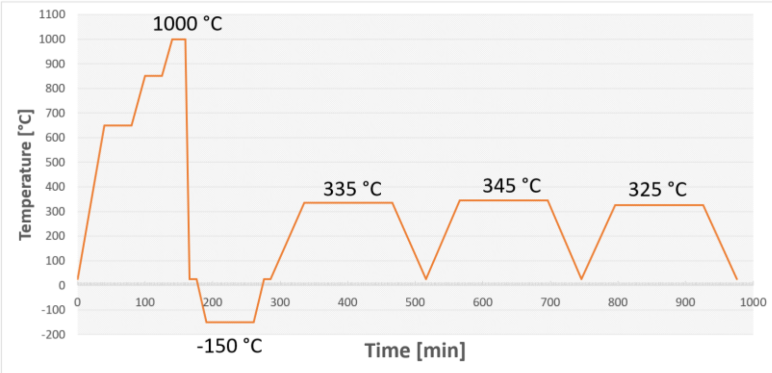

Fig. 3. Heat treatment diagram of the cryogenically treated specimen

The wear resistance tests were concluded on samples with a polished surface, using a unique ball wear equipment (Fig. 4.), which was made by the Material Science Department, at Bánki Donát Faculty of Mechanical and Safety Engineering, Óbuda University, according to an article written by Tünde Kovács, and László Dévényi [10]. The wear marks were examined with an Olympus DSX10 type microscope, made in Japan.

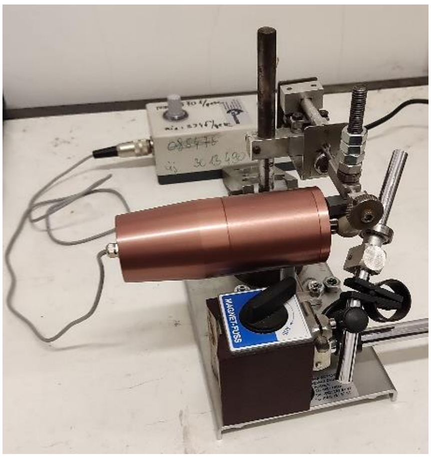

Fig. 4. Abrasive wear equipment

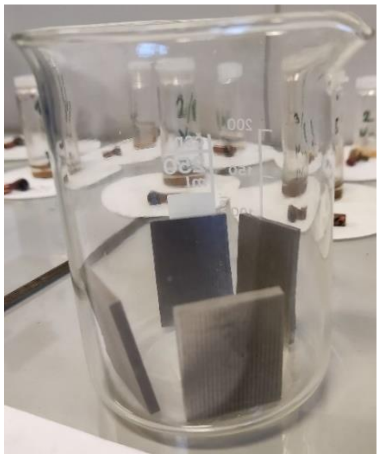

Fig. 5. Samples before submerging in the $FeCl_3$ solution

The corrosion tests were carried out according to the ASTM G48-11R20E01 method "B" standard specifications on polished surface samples (at room temperature, for 72 hours, in a 6 % $FeCl_3$ solution).

Results

The measured hardness values are listed in the table 2.

Table 2. Average hardness values

	In delivery state	Conventionally heat treated	Cryogenicly treated
Brinell Hardness (HB)	253	-	-
Rockwell Scale C Hardness (HR_C)	-	54	55

Based on the wear marks, the wear factors can be calculated [10]:

$$K = \frac{V_v}{S \times N} \left[\frac{mm^3}{Nm}\right] \quad (1)$$

K: wear factor [mm^3/Nm]
V_v: abrasion volume loss [mm^3]
S: wear path length [m]
N: loading force [N]

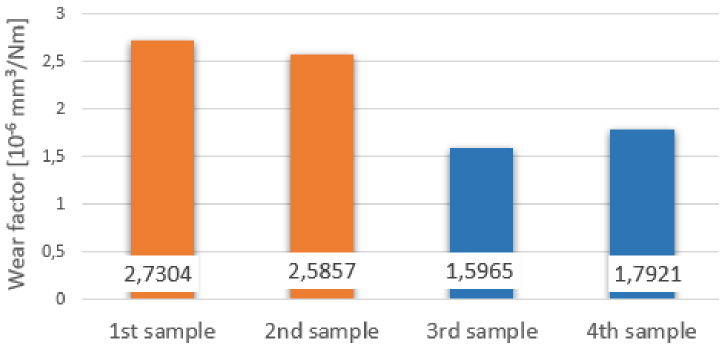

Fig. 6. Average values of wear factors

In the diagram the first two samples are conventionally heat treated, the last two are cryogenically treated.

When calculating the corrosion weight loss [12], we need to measure the difference in mass (Δm) before and after the corrosion tests [g], their surface area(A) [m^2], and the duration (t) the samples were submerged [h]:

$$Corrosion\ weight\ loss = \frac{\Delta m}{A \times t} \left[\frac{g}{m^2 h}\right] \quad (2)$$

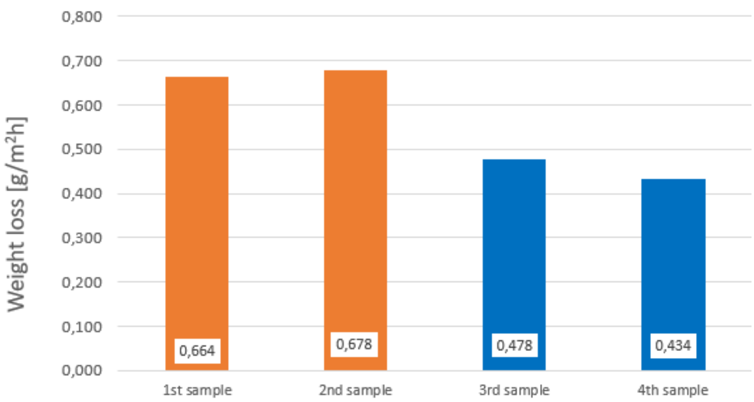

Fig. 7. Average corrosion weight loss

On the diagram above, the conventionally heat treated samples are shown in orange, and the cryogenically treated ones in blue.

Conclusions

We carried out experiments to determine the properties of the tool steel based on two types of heat treatment technologies. The obtained results indicate, that by using shallow cryogenic treatment, we can improve the wear and corrosion resistance properties of the used steel grade by at least 40 %. This also suggests that tools made of this material may have longer lifetime if they are used in these conditions.

In order to confirm the usefulness of this method, it may be necessary to use this steel grade and heat treatment technology to create a plastic mould tool, which is used in highly abrasive and corrosive environments, like PVC granulation.

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