EUROPEAN JOURNAL OF MATERIALS SCIENCE AND ENGINEERING
Volume 7, Issue 4, 2022: 299-305 | www.ejmse.ro | ISSN: 2537-4338

DOI: 10.36868/ejmse.2022.07.04.299

POSSIBILITY FOR IMPROVING THE PROPERTIES OF THE PLASTIC MOULD TOOL IN ORDER TO INCREASE ITS SERVICE LIFE

László TÓTH[1*], Enikő Réka FÁBIÁN[1]

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

Abstract

Injection moulding of grain-reinforced and fibre-reinforced polymers exposes the injection moulding tool to severe wear. The microstructure of the tool affects its hardness, wear resistance and the tool life. In this work were studied two different heat treatment technologies effects on the properties of Böhler M340 ISOPLAST steel, which was manufactured by electroslag remelting. There were studied the hardness, the toughness and the microstructure. At sample which was triple tempered after conventional quench to room temperature appears some residual austenite in tempered martensite, near primary and secondary carbides, at cryogenically quenched sample higher hardness and no residual austenite was observed. The results show that cryogenically quenching and triple tempering at high temperature gives the injection moulding tool longer life than conventional heat treatment.

Keywords*:* *plastic mould tool, tool life, deep cryogenic treatment, retained austenite***.**

Introduction

Choosing the right tool steel and its best heat treatment technologies for the application becomes more and more important as the demands on the tool life increase. Harsh environmental conditions put the tools under considerable stress. Corrosion, high temperature changes and wear are just few of the most common challenges that tool users have to deal with, not to mention the expected quality of the final product. To corrosion or wear stresses, especially in the processing of fibre-reinforced plastics are the most important decision criteria. Good machinability and heat treatment are self-evident.

Maintenance of a used tool, which may consist of cleaning, polishing, welding, stress-relieving and replacement of broken or worm parts, can be quite expensive. Outgoings due to shutdowns, such as loss of production, downtime, wages, penalties due to late delivery, and loss of customers can also cause significant costs. It is in the interest of the components manufacturers that the lifetime of the production tool be as long as possible and the cost of the parts should be as low as possible. For the mould maker it is important the raw material machinability, grindability, polishability, EDM machinability, dimensional stability during heat treatment. The manufacturer is looking for a mould with good wear and corrosion resistance, high compressive strength etc. The cost of the raw material of tool steel in a mould represents approx. 5-10% of the tool costs. The effect on the total cost will be even less.

Corrosion damages the tools, and can cause deformations and dimensional changes in them, resulting in an unsuitable product. Corrosion cam block it the cooling water channels in the tools, which can lead to the failure of the tool or product. During the production of PVC plastic products, chlorine gases are generated which strongly influenced the corrosion of plastic

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

moulds. In this case, it is important to use a quality of tool steel that is resistant to this or similar harmful effects.

To achieve the right properties of the tools it is very important to use the right heat treatment. The desired properties and the appropriate work hardness can be achieved by using correctly and carefully designed heat treatment technology. Such properties could be the toughness, compression strength, wear resistance and corrosion resistance. High hardness results appear in good wear resistance, increased compressive strength, when the hardness is low better toughness can be achieved. A normal working hardness for through hardened steel is 46-60 HRC. To determine the right working hardness must be taken into account the tool steel quality, the product dimensions and geometry, the production process, the product quality and quantity etc.

Taking all this requirements and desires in consideration for a plastic extrusion and recycling die tool we analysed the Böhler M340 ISOPLAST plastic mould steel subjected to different heat treatment technologies. Böhler M340 ISOPLAST is a high performance plastic mould steel with excellent corrosion resistance properties, suitable for heat treatment in vacuum furnaces, fine carbide structure, good dimensional stability with appropriate heat treatment, excellent high wear resistance, good machinability, good polishability [1,2]. The best properties for corrosion resistance and wear resistance at some special tool steels are achieved with cryogenic heat treatment [3]. The Böhler M340 ISOPLAST steel is clean, has a homogeneous microstructure with fine carbide distribution thanks to pressure electroslag remelting (PESR) technology [4]. Böhler M340 ISOPLAST has been highly demanded in different industries for its steadiness in several requirements like highest precision parts, processability of plastics containing abrasive and corrosive fillers, elevated processing temperatures, higher tool economy, applications for food processing, instruments and knives typical for cutting applications.

The plastic tool life is determined mainly by the material quality. The properties of the tool can be achieved by heat treatment. For plastic extrusion a recycling tools we chosen the Böhler M340 ISOPLAST quality grade due to their high performance and very good mechanical and tribological properties. The purpose of heat treatment a plastic mould steel tool is to obtain suitable properties as wear and corrosive resistance, toughness and strength. The principal problems that arise in association with heat treatment are the distortion, dimensional changes, decarbonization, carburization, grain boundary precipitation. The distortions on tools result from machining stresses, thermal stresses and microstructural transformation stresses. A good way to prevent these problems is to use the cryogenic treatments. Using cryogenic treatment can be reduced the retained austenite [5-7]. Reducing the retained austenite in tools can be prevent distortions and dimensional changes. Dimensional changes occur both in hardening and tempering [8]. The used heat treatment in tool manufacturing is the conventional heat treatment (CHT), which consist in heating up to $A_{c\ cem}$ transformation for austenitization, hold it there for austenite homogenization followed by rapid quenching for martensitic transformation, and double or triple tempering to adjust the required hardness [9]. The microstructure of this steel after CHT consist of tempered martensite, martensite, primary carbides, secondary precipitated carbides and retained austenite [10]. In case of cryogenic treatment (DCT) after austenitizing the tool is cooled to sub zero degree Celsius to complete the austenite-martensite transformation. Sub zero cooling steps continues with three times high temperature tempering resulting a microstructure with small secondary carbides and minimal amount of retained austenite [11]. The formed secondary carbides reduce internal stress of the martensite, increases toughness and form buffers for the microcrack propagations, resulting a more homogenous microstructure [12].

The aim of this experimental study is to find the most suitable tool steel material and its heat treatment to increase the plastic mould tool service life.

Materials and Methods

After the comprehensive study of the literature for the plastic extrusion tool we are selected the Böhler M340 ISOPLAST tool steel quality manufactured with electroslag remelting technology. The chemical composition of the steel (Table 1) was analysed with a Hitachi PMP2 type instrument (Fig. 1). The specimens was heat treated in IVA Schmetz IU72 type horizontal vacuum furnace (Fig. 2).

Table 1. Chemical composition of the Böhler M340 ISOPLAST plastic mould steel

Elem.	**C**	**Si**	**Mn**	**Cr**	**Mo**	**V**
%, wt.	0.52	0.42	0.41	17.10	1.12	0.11

The heat treatments process was controlled by the thermocouple fixed in the centre of the specimen, based on the heat treatment diagrams (Fig. 3). The specimens were preheated in the vacuum furnace to 650°C and held it for temperature equalization between the core and surface. The second holding steps is at 850°C and the third is at 1000°C the austenitization temperature. After austenitization the first specimen was conventionally (CHT) cooled with 9 bar nitrogen gas to the room temperature followed the three times tempering (510,520,500°C) (Fig.3.).

The second specimen was deep cryogenically treated (DCT), which means that cooling continued using liquid nitrogen from room temperature till minus 150°C. After 70 minutes holding time, the process continued with three times tempering (480, 490, 470°C) (Fig. 3).

Fig. 1. Specimens in the ultrasonic washer

Fig. 2. IVA Schmetz vacuum furnace

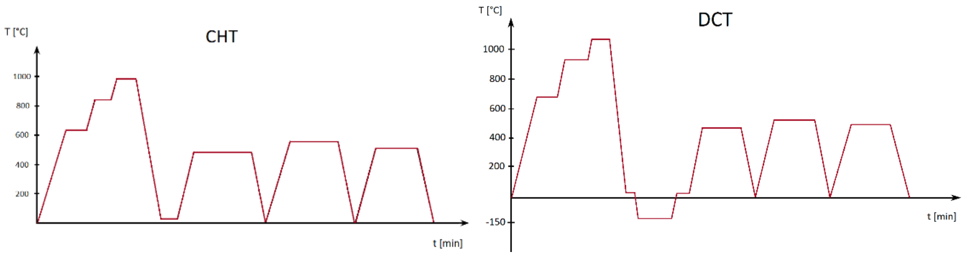

Fig. 3. The heat treatment diagrams of the tool steel with CHT respectively DCT

Results and Discussions

Before and after the heat treatment the specimens hardness was measured with an universal hardness tester type ERST 130D. The results are presented in table nr. 2. The hardness before the heat treatment in delivery condition was the same 241 HB. After the heat treatments the DCT treated specimen hardness it was with 1 HRC higher than the CHT specimen which is due to sub zero treatment cooling.

Table 2. Hardness results

Specimen	Before heat treatment	After heat treatment
CHT	241 HB	55 HRC
DCT	241 HB	56 HRC

The microstructures of the specimens after the metallographic preparation (grinding, polishing and etching with Nital) was analysed using optical microscope type Olympus DSX100 (Fig. 4). Scanning electron microscope type JSM 5310 (Fig.5) was used for the study of the fractured surface after impact test.

Fig. 4. Olympus DSX 100 optical microscope

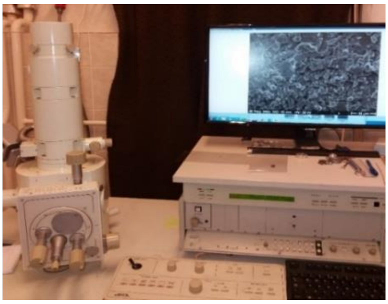

Fig. 5. Jeol 5310 electron microscope

At low magnification, the size and character of the original primary carbide net in conventionally heat-treated samples (CHT) can be better recognized than in the microstructure of the deep cryogenically treated (DCT) piece, even though the carbide network is not continuous in either case as are show on Fig.6 and Fig. 7. In case of all samples, the edges of the primary carbides are rounded, and this phenomenon is more pronounced in the deep cryogenically treated sample.

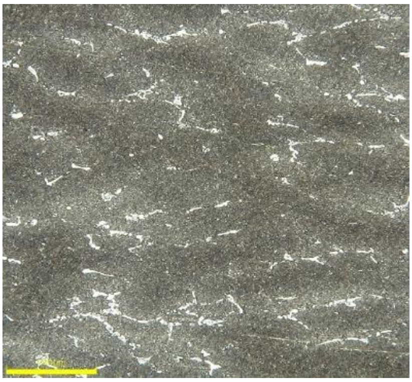

Fig. 6. Microstructures of CHT treated specimen

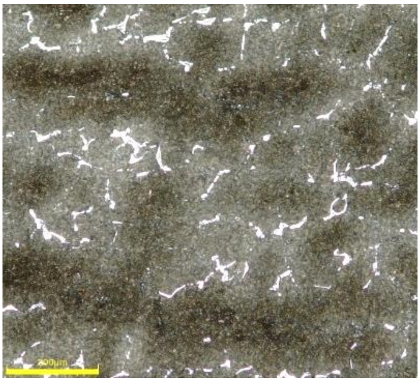

Fig. 7. Microstructures of DCT treated specimen

Studying the matrix of the samples at high resolution revealed several differences. The microstructure of the CHT specimen (Fig. 8) show a tempered structure with primary carbides (PC), tempered martensite (TM), small secondary carbides (SSC) and residual austenite (RA). In the picture from Fig. 9 we can see tempered martensite (TM), primary carbides and small secondary carbides.

The difference in hardness can be explained by differences in the microstructure of the matrix.

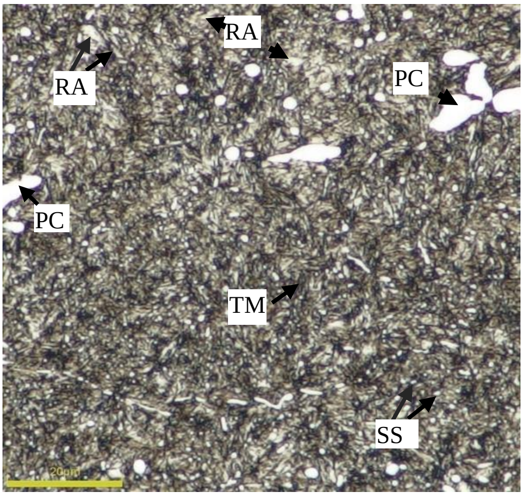

Fig. 8. Microstructures of CHT treated specimen

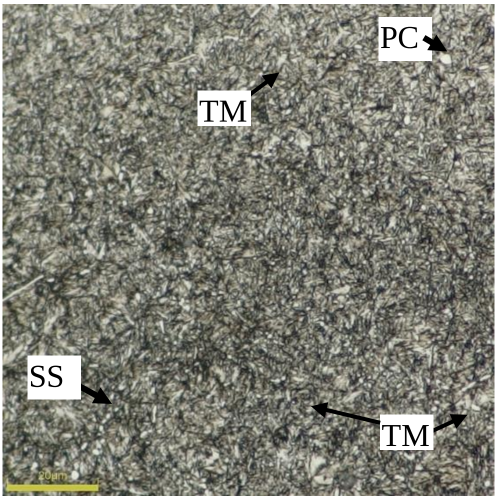

Fig. 9.Microstructures of DCT treated specimen

The scanning electron micrographs on Fig. 10. represent the fractured surface of the CHT specimen and the SEM spectrum of the local chemical composition.

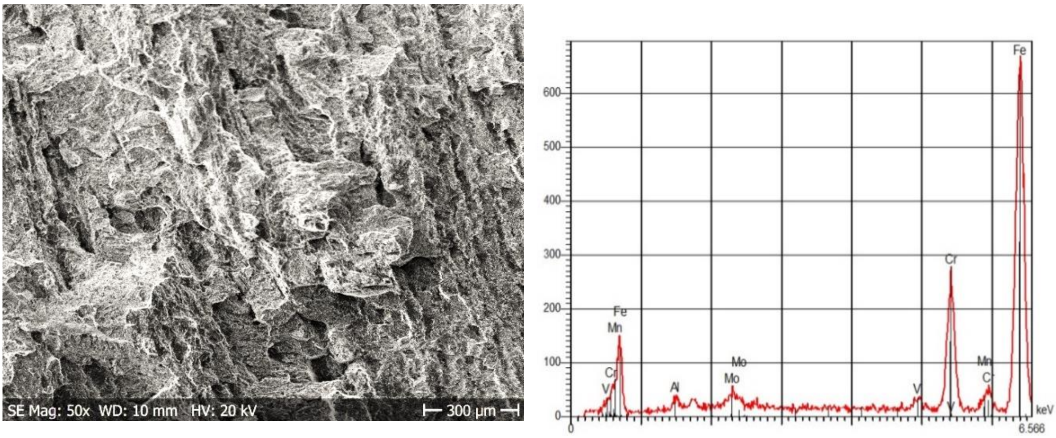

Fig. 10. The fractured surface and the spectrum of the CHT treated specimen

The scanning electron micrographs on Fig. 11. represent the fractured surface of the DCT specimen and the SEM spectrum of the local chemical composition.

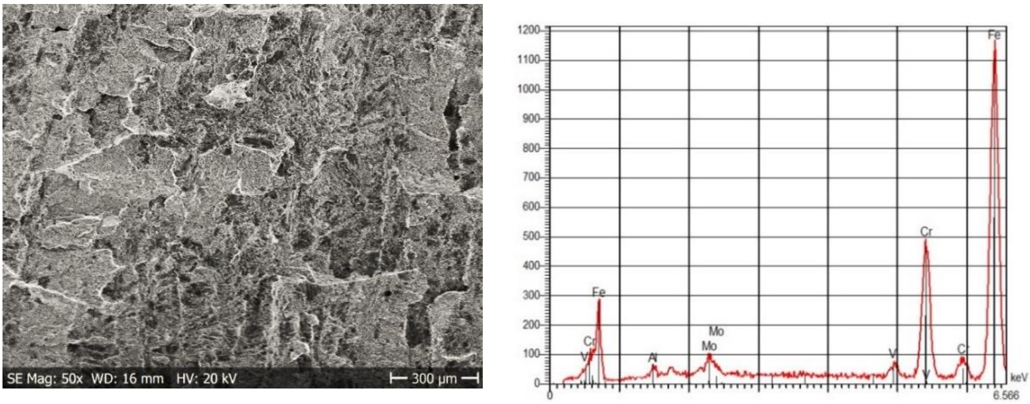

Fig. 11. The fractured surface and the spectrum of the DCT treated specimen

All the fractures are rigid, but the CHT sample appears to be more rigid. We did not find much difference in the chemical composition of the fractures tested, neither in terms of weight % (W%) nor in atom % (A%).

Conclusion

Heat treatment in vacuum furnaces result no surface decarburization and oxidation. Cryogenically heat treatment after austenitisation and triple tempering resulted finer microstructure, than in the case of conventional heat treatment. In case of cryogenically treated sample no retained austenite was observed in the matrix. this can explain the higher hardness of DCT sample. The fractured surface of the DCT sample appears less brittle than that of the CHT sample.

Acknowledgement

The authors would like to thank the Hungarian State, the National Research, Development and Innovation Office and the European Union for their support in project No. 2020-1.1.2-PIACI-KFI-2020-00081

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Received: November 05, 2022
Accepted: December 01, 2022