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The Impact of Tempering Temperature on Retained Austenite and Mechanical Properties of 1.2842 Tool Steel

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Abstract

This work investigates the impact of tempering temperature on the mechanical properties quenched 1.2842 (O2) cold work tool steel depending on the volume fraction of retained austenite (RA). The tempering temperature significantly influences proportion of RA and the mechanical properties. Therefore, the tempering temperature and the volume fractions of RA in through-hardened tool steels must be optimized to minimize dimensional variations and augment performance in service. In this work, the hardened samples were subjected to tempering process at different tempering temperatures and hardnes, impact and tensile tests were applied to the samples. Then the results obtained from these tests were analyzed and optimum tempering temperature was defined. The findings reveal that low-temperature tempering leads to a robust stabilization of the RA phase and better mechanical properties for the steel investigated.

Keywords: Cold work tool steel, Tempering temperature, Retained austenite, Mechanical properties

Temperleme Sıcaklığının Kalıntı Östenit ve 1.2842 Takım Çeliğinin Mekanik Özelliklerine Etkisi

Öz

Bu çalışmada, temperleme sıcaklığı ve kalıntı östenit miktarının, sertleştirilme işlemine tabi tutulmuş 1.2842 (O2) soğuk iş takım çeliğinin mekanik özelliklerine etkisi araştırılmıştır. Sertleştirme ısıl işlemi sonrası uygulanan temperleme işlemlerinde sıcaklığı kalıntı östenit miktarını önemli derecede etkilemektedir. Bu nedenden ısıl işlemler sonrası istenilen mekanik özelliklerinin elde edilebilmesi için kalıntı östenit miktarı ve temperleme sıcaklığının optimize edilmesi gerekmektedir. Bu çalışmada, sertleştirilmiş ve farklı sıcaklıklarda temperleme işlemine tabi tutulmuş numunelerde elde edilen sertlik, tokluk, çekme dayanımı ve yüzde uzama değerlerini belirlemek için sırası ile sertlik, çentik darbe ve çekme testleri yapılmıştır. Bu testlerde elde edilen sonuçlar analiz edilerek optimum temperleme sıcaklığı

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belirlenmiştir. Deneylerden elde edilen sonuçlara göre 1.2842 soğuk iş takım çeliği için kalıntı östenit miktarının en olumlu etkisi ve en uygun mekanik özelliklerin düşük temperleme sıcaklığında olduğu gözlenmiştir.

Anahtar Kelimeler: Soğuk iş takım çeliği, Temperleme sıcaklığı, Kalıntı ostenit, Mekanik özellikler

1. INTRODUCTION

Steels used for tooling applications are usually supplied in the annealed condition to simplify machining and other operations [1]. However, this condition of steel has a low hardness and wear resistance. Therefore, tool steels are subjected to various heat treatment processes at different conditions according to the steel type and service requirements. These processes increase the tool's service performance, contingent on the proper selection of steel and the correct application of heat treatment processes [2].

The first heat treatment process is quenching. The microstructure of tool steels obtained after the hardening process composed of martensite and austenite that does not transformed to martensite. Untransformed austenite is called Retained Austenite (RA). The mechanical properties of tool steels such as fatigue resistance and impact toughness are highly affected by the amount of RA content. Generally, an optimal amount of RA can bolster ductility and toughness, whereas an excess can impair the dimensional stability, strength, and wear resistance of steel components. Therefore, it is important to select proper heat treatment conditions for achieving optimal service life and mechanical properties [3-6].

Tempering process is applied after the quenching processes to reduce the brittleness add improve toughness of martensitic structure and to increase its ductility and toughness. The tempering conditions influences proportion of RA and the mechanical properties. Therefore, it is one of the critical step during heat treatment of tool steels. Many studies have been performed in order to determine the optimum tempering temperatures depending on the grade of steel [7-9].

This work explores the effect of tempering temperature on the mechanical properties of quenched 1.2842 (O2) cold work tool steel depending on the amount retained austenite. The volume fraction of retained austenite obtained after the tempering process was determined at by using X-ray diffraction method. [10,11]. The analysis assessed different tempering temperatures and evaluating the impacts on the mechanical properties of the 1.2842 tool steel.

2. MATERIALS AND METHODS

2.1. Materials

The subject of this investigation was commercially available 1.2842 cold work tool steel, a common member of high carbon steels with modest alloy additions. A breakdown of the steel's chemical make-up is found in Table 1. The cost-effective nature of this steel category, paired with its suitability for forming dies that demand hard surfaces and stability during hardening, makes it a popular choice.

Table 1. Breakdown of chemical composition of 1.2842 steel utilized in the tests (% by weight)

C	Si	Mn	Cr	Mo	Ni	V	W	P
0.90	0.25	2.00	0.40	-	-	0.10	-	0.03

2.2. Heat Treatment Procedure

The study incorporated hardening and tempering processes under the conditions detailed in Table 2, in line with the recommended technical procedures for 1.2842 steel heat treatment.

The test specimens were first stress-relieved at 400°C for 2 hours, austenitized at 820°C for a half-hour, and oil-quenched. Further stress-relieving preceded the tempering stage at 150°C to prevent cracking or warping. Subsequently, the samples were tempered in an electrical muffle furnace at varying temperatures for 90 minutes and cooled in still air. The tempering temperatures were informed by the kinetics of diffusional phase transformation during heating from the quenched state, as detailed by Continuous Heating Transformations diagrams (CHT) [12].

Table 2. Heat treatment parameters

	Temperature (ºC)	Time (h)	Medium
Stress relieving	400	2	Furnace
Hardening	820	0.5	Oil
Tempering	150	1.5	Still air
	200		
	250		
	300		
	400		

2.3. Hardness Testing

Rockwell C hardness was measured on the specimens at room temperature, with the average hardness taken from at least three readings for each tempering temperature. The average values were plotted against tempering temperatures for interpretation.

2.4. Impact Testing

V-notch test was executed at room temperature using a 300 J Charpy tester. Samples, measuring 10x10x55 mm and treated at varied temperatures, were subjected to this test.

2.5. Tensile Testing

Tests were conducted on a 100-ton capacity hydraulic load-controlled tensile testing machine, in accordance with ASTM E8M-04. This facilitated a comprehensive examination of the tensile properties of specimens conditioned under different circumstances.

3. RESULTS AND DISCUSSION

3.1. Hardness

Figure 1 illustrates the average hardness and the proportion of Retained Austenite (RA) across varying tempering temperatures. As anticipated, the maximum hardness was achieved under as-quenched conditions due to the extensive distortion in the lattice during martensite formation. The hardness of the examined samples decreased at varied rates as the tempering temperature rose to 400ºC.

Within a tempering temperature of roughly 150ºC, a minor decrease in hardness to 62 HRC occurred, mainly due to reduced RA content. This highlights that the combination of high dislocation density and precipitation of epsilon carbides contributed to a less significant reduction in hardness within this temperature range. An increase in tempering temperature to around 200ºC led to a more pronounced reduction in hardness (from 64 to 57 HRC). The volume fraction of RA reached a local maximum at this temperature, linking the soft RA to the decline in hardness numbers.

In the tempering temperature ranges of 200ºC to 250ºC and 250ºC to 300ºC, hardness values dropped to 53 and 51 HRC, respectively. This occurred because the volume fraction of retained austenite started to gradually decline in these ranges, as corroborated by Kokosza and Pacyna [13]. Secondary hardening effects were absent in the tempering range of 150°C to 400°C, a result of the minimal carbide-forming elements in the examined steel that would typically elevate hardness at higher tempering temperatures.

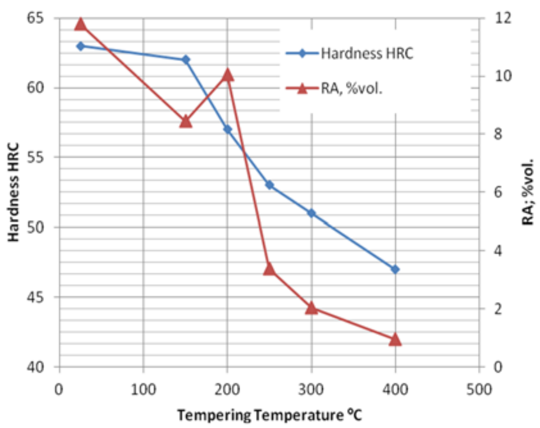

Figure 1. Hardness and RA as a function of tempering temperature

3.2. Impact Toughness

Austenite, besides being robust, exhibits greater impact strength than martensite, leading to a positive correlation between the steel's impact strength and its austenite content.

Figure 2 presents the results of impact tests performed at room temperature and RA volume as functions of tempering temperature. Increasing the temperature from 150ºC to 200ºC resulted in an enhancement of material impact toughness, peaking at 200ºC, coinciding with a local maximum in RA volume (Figure 2). Other researchers reported similar findings, connecting the increment in impact toughness at this temperature directly to RA [13,14].

Impact toughness is decreased and reached local minimum at around 250ºC, a result of reduced RA volume fraction and the influence of tempered martensite embrittlement. According to Herring and Euser [15,16], segregation of elements like phosphorus and sulphur to austenite grain boundaries causes this reduction. Further studies by other researchers [17,18] revealed that the higher amount of Mn and Si can accelerate this segregation, contributing to tempered martensite embrittlement in the temperature range of 200-250ºC.

Above 250ºC, tempering led to higher impact toughness due to advancements in the tempering processes and structural coarsening.

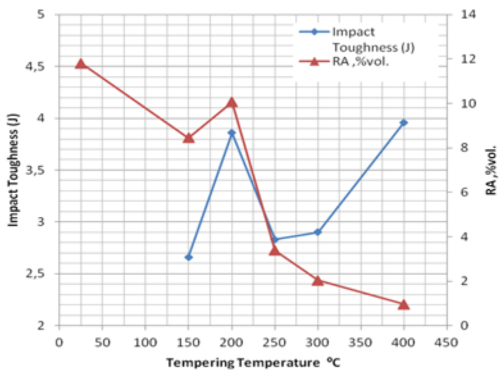

Figure 2. Impact toughness and RA as a function of tempering temperature

3.3. Tensile Properties

Following quenching, specimens were tempered for 90 minutes at temperatures ranging from 150°C to 400°C and subjected to tensile testing. The results, illustrated in Figure 3, demonstrate the steel's sensitivity to tempering temperature. Both yield and ultimate tensile strength declined with increasing tempering temperatures, a known effect of carbon diffusion in cementite, which diminishes the strength of tempered martensite while increasing its ductility.

Figure 3 shows that tempered martensite embrittlement occurred in the range of approximately 200-250ºC, tensile properties were relatively unaffected. As Herring [15] noted, this phenomenon doesn't affect room-temperature tensile properties but can significantly reduce impact toughness and fatigue performance.

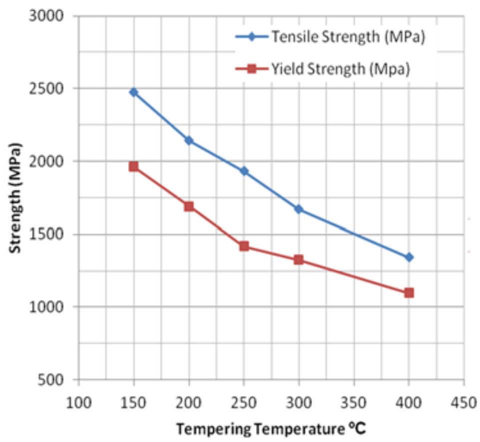

Figure 3. Ultimate tensile strength and 0.2% yield strength against the tempering temperature

Figure 4 displays the percent elongation and hardness as a function of tempering temperatures. With the increment in tempering temperature, the percent elongation increased, peaking at 400ºC. There appears to be an opposite relationship between material ductility and hardness as deduced from experimental observations.

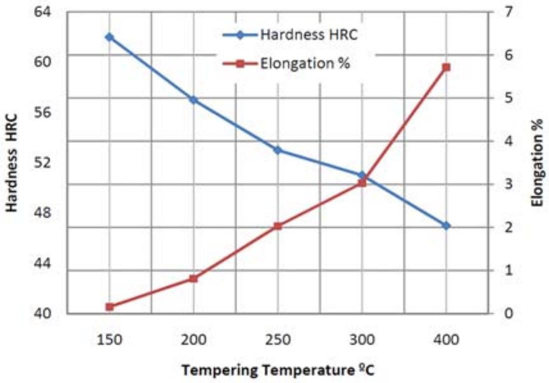

Figure 4. Hardness and percent elongation as a function of tempering temperature.

4. CONCLUSION

This study evaluated the mechanical properties of quenched and tempered 1.2842 tool steel depending on the tempering temperature and amount RA. Figure 5 summarizes the relationship between tempering temperature, retained austenite and mechanical properties of investigated steel.

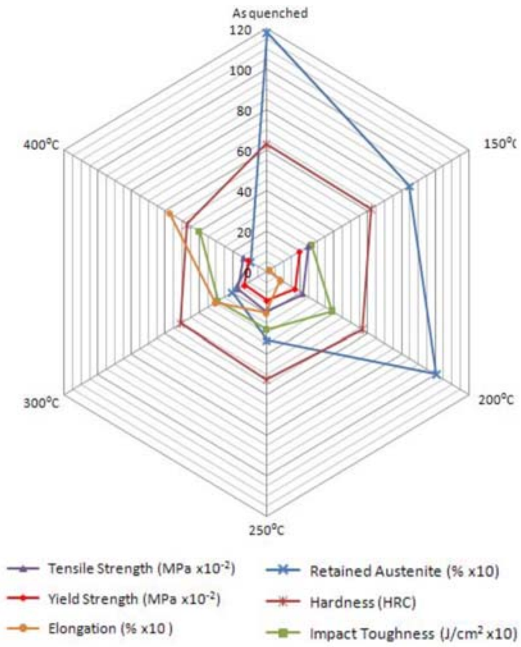

Figure 5. The relationship between tempering temperature, RA and mechanical properties of 1.2842 tool steel

Several key conclusions were drawn:

The hardness decreased gradually with increased tempering temperature, though the reduction was not uniform.

No secondary hardening effect was observed between 150°C and 400°C.

Impact toughness dropped suddenly from 200 to 250°C due to factors including RA transformation and segregation of minor elements.

Yield strength and ultimate tensile strength decreased within the range of 150-200ºC, with no significant effect from tempered martensite embrittlement.

Percent elongation increased with tempering temperature, peaking at 400ºC.

The results indicate that a tempering temperature range of about 180-220°C is recommended for tempering 1.2842 tool steel, considering the effects on hardness, tensile properties, and impact toughness.

This analysis offers a comprehensive understanding of how tempering temperature affects various properties of 1.2842 tool steel, providing valuable insights for industrial applications and further research.

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6. REFERENCES

1. Heat Treatment of Tool Steels, https://www.thefreelibrary.com/Heat+treatment+of+tool+steels.-a066123648, Access date: Sep. 07 2023.
2. Uchegbulam, I., Abeer, A.S., Nnorom, O., 2019. Heat Treatment of UNS T72305 Tool

Steel: Effect on Mechanical and Microstructural Properties. The International Journal of Engineering and Science 8(9), 50-56.

3. Tabatabae, B.A., Ashrafızadeh, F., Hasanlı, A.M., 2011. Influence of Retained Austenite on the Mechanical Properties of Low Carbon Martensitic Stainless Steel Castings. The International Journal of Engineering and Science (ISIJ), 51(3), 471-475**.**

4. Feng, Y., Jing, C., Lin, T., Wu, Z., Li, Z., Zhao. J., 2023. Effect of Retained Austenite on the Microstructure and Mechanical Properties of Cold-rolled Medium-manganese Q&P Steel. Iron & Steelmaking Processes, Products and Applications, 50(2), 167-173.

5. Saastamoinen, A., Kaijalainen, A., Nyo, T.T., Suikkanen, P., Porter, D., Kömi, J., 2019. Direct-Quenched and Tempered Low-C High-Strength Structural Steel: The Role of Chemical Composition on Microstructure and Mechanical Properties. Materials Science & Engineering: A, 760, 346-358.

6. Podgornik, B., Puš, G., Žužek, B., Leskovšek, V., Godec, M., 2017. Heat Treatment Optimization and Properties Correlation for H11-Type Hot-Work Tool Steel. Met. Mater. Trans. A, 49(2), 455-462.

7. Zhang, Y., Zhan, D., Qi, X., Jiang, Z., 2019. Effect of Tempering Temperature on the Microstructure and Properties of Ultra High Strength Stainless Steel. Journal of Materials Science and Technology, 35(7), 1240-1249.

8. Chen, K., Jiang, Z., Liu, F., Yu, J., Li, Y., Gong, W., Chen, C., 2019. Effect of Quenching and Tempering Temperature on Microstructure and Tensile Properties of Microalloyed Ultra-high Strength Suspension Spring Steel. Materials Science and Engineering: A, 766, 1-11.

9. Bae, K., Moon, H.S., Park, Y., Jo, I., Lee, J., 2022. Influence of Tempering Temperature and Time on Microstructure and Mechanical Properties of Additively Manufactured H13 Tool Steel. Materials (Basel), 15(23), 1-10.

10. Günerli E., Bayramoglu M., Geren N., 2022. Volume Fraction of Retained Austenite in 1.2842 Tool Steel as a Function of Tempering Temperature. European Mechanical Science, 6(4), 263-268.

11. Gunerli, E., 2012. Effect of Tempering Temperature on the Mechanical Properties of Hardened 1.2842 Tool Steel, MSc diss., Institute of Natural and Applied Sciences**,** University of Cukurova, Adana, 108.

12. Bala, P., Pacyna, J., Krawczyk, J., 2009. The Kinetics of Phase Transformations During the Tempering HS6-5-2 Steel. Archives of Materials Science and Engineering, 35(2), 69-76.

13. Kokosza, A., Pacyna, J., 2008. Effect of Retained Austenite on the Fracture Toughness of Tempered Tool Steel. Archives of Materials Science and Engineering, 31(2), 87-90.

14. Zhou, S.B., Hu, F., Zhou, W., Cheng, L., Hu, C.Y., Wu, K.M., 2021. Effect of Retained Austenite on Impact Toughness and Fracture Behavior of Medium Carbon Submicron-Structured Bainitic Steel. Journal of Materials Research and Technology, 14, 1021-1034

15. Herring, D.H., 2006. The Embrittlement Phenomena in Hardened and Tempered Steel. Industrial Heating, 10, 16-18.

16. Euser, V.K., Don, L.W., Kip, O.F., Amy, J.C., Speer, J.G., 2021. The Role of Retained Austenite in Tempered Martensite Embrittlement of 4340 and 300-M Steels Investigated Through Rapid Tempering. Metals, 11(9), 1-12.

17. Spink, G.M., 1977. Reversible Temper Embrittlement of Rotor Steels. Metallurgical Transactions A, 8(1), 135-143.

18. Bandyopadhyay, N., McMahon, C.J., 1983. The Micro-mechanisms of Tempered Martensite Embrittlement in 4340-type Steels. Metall Trans A, 14, 1313-1325.