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The Impact of Cryogenic Treatment and Temper to Wear Resistance of MDI (Martemper Ductile Iron)

Agus Suprapto*, Agus Iswantoko and Ike Widyastuti

Mechanical Engineering Department, Faculty of Engineering,
University of Merdeka Malang, Jl. Terusan Raya Dieng 62-64 Malang.

Abstract

Generally, case hardening and the addition of chemical elements are the alternatives to solve wear metals in order to reduce friction. Nowadays, many industries develop cryogenic treatment to improve wear resistance of ductile iron material to increase wear resistance is. The purpose of this study to evaluate the impact of cryogenic treatment and temper for hardness and wear resistance of Martemper Ductile Iron (MDI). The method used in this study is cryogenic treatment and temper of Martemper Ductile Iron (MDI) by heating in the austenite temperature of 900^0C for 30 minutes, then quenching in warm water at the temperature 40^0C, 60^0C, 80^0C with holding time variation 60s, 120s, 180s and cooled at room temperature. Test analysis is conducted by analytical method and hardness test with Rockwell method and wear test. Findings from this research: (1). Hardness of Martemper is 51.33 HRc, 55.33 HRc for Cryogenic Treatment and 56,00 HRc for Temper, showed an increasing of hardness. (2). Result of Cryogenic Treatment indicate an increasing of wear resistance by 83% compare to the results of Martemper. (3). Result of Temper indicate an increasing in wear resistance by 3.5% compare with the results of Cryogenic Treatment.

Keywords: Martemper, MDI, Martemper, Cryogenic Treatment, temper

INTRODUCTION

The development of cryogenic treatment is to improve the wear resistance of cutting tools, gear, and others (Thamizhmanii, S. et al, 2011; Ramji B.R. et al, 2010; Kollmer K.P, 2007). Cryogenic treatment is a process of cooling a steel material, stainless steel and others, from room temperature up to -320^0F (-196^0C), retained for a certain period of time, then followed by warming to room temperature (Singh, S. et al 2012 and Ramji BR et al, 2010).

Research result by A Suprapto, et al., (2016) showed a decreasing of 77% in wear as the result of Cryogenic Treatment on ADI (Austemper Ductile Iron) tool. Research on cryogenic treatment also conducted by Chang-Yong Kang et al., (2009) on ADI (Austemper Ductile Iron) which indicates the increase in hardness for 18% as the result of Subzero Treatment. It is supported by research by Suriansyah et al (2015) which shows the influence of cryogenic cooling, martemper and temper treatment on FCD-45, increasing 9% in hardness compare to pre-treatment condition.

Methods developed by Akinlabi Q, et al., (2013) using Martempered Ductile Iron (MDI) with Quenching in warm water obtained the highest hardness about 52.9 HRc

As the follow up on previous researches conducted by Chang-Yong Kang et al (2009); A Suprapto, et al., (2016); Suriansyah et al., (2015); and Akinlabi Q, et al., (2013), this study combines Cryogenic treatment with Martemper process on Material Ductile Iron (MDI), to observe the effect of hardness and wear resistance properties of MDI (Martemper Ductile Iron).

TESTING METHOD

Martemper Ductile Iron (MDI)

- FCD-45 material heated until *Austenit* temperature of 900^0C with holding time 1 hour
- Quenching in warm water with the temperatures of 40^0C, 60^0C, 80^0C with holding time 60s, 120s and 180s
- Cooling to room temperature

Cryogenic treatment MDI

- Cooling in liquid nitrogen
- Holding time in liquid nitrogen is varied: 2 hours, 24 hours, 48 hours
- Heating until room temperature

Hardness Test

- Scale-C Rockwell method
- Using diamond identor with minor load of 10 kg and major load150 kg

Wear Test

- Weighing of initial weight and final weight of the sample (g)
- Load 15 kg, spin speed 750 rpm, slide range 295 mm
- Loading time 5 minutes

RESULTS AND DISCUSSION

Hardness

Table 1. The result hardness of *Martemper Ductile Iron* process in warm water media with temperature variations and holding time 60 s, and Cryogenic treatment with Temper.

	HRc		
Condition	T 40^0 C	T 60^0 C	T 80^0 C
Martemper (Cryogenic Untreatment)	51.33	46.67	48.33
Nitrogen 2 jam	53.67	51.67	55.33
Nitrogen 24 jam	54.00	53.33	54.67
Nitrogen 48 jam	55.33	53.33	52.67
Nitrogen 2 jam + Temper 150^0 C	54.33	53.00	55.33
Nitrogen 24 jam + Temper 150^0 C	55.33	54.33	53.67
Nitrogen 48 jam + Temper 150^0 C	56.00	56.00	52.00

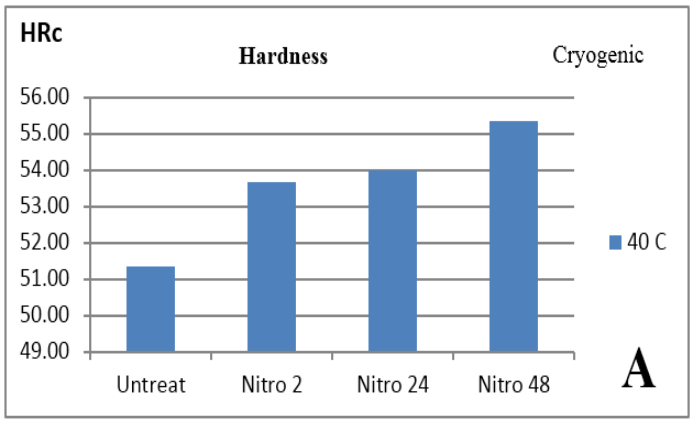

Figure 1. A. The hardness of Martemper Ductile Iron in warm water media at the temperature of 40^0C with holding time 60 second, continued with Cryogenic treatment process holding time variance in liquid nitrogen of 2 hours, 24 hours and 48 hours.

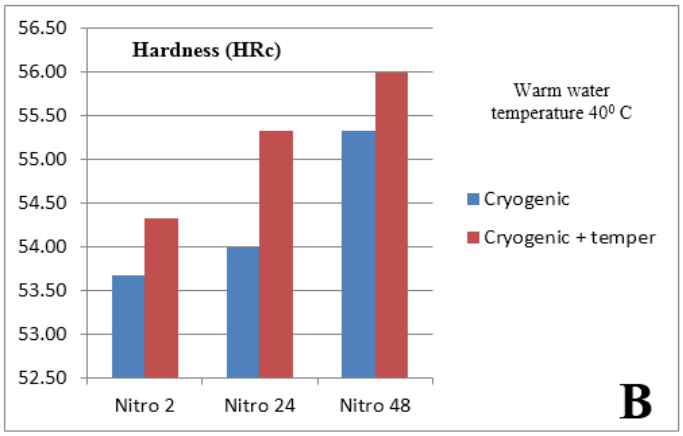

Figure 1 B. The result hardness of Cryogenic treatment process continued with 150^0 C temper for 1 hour.

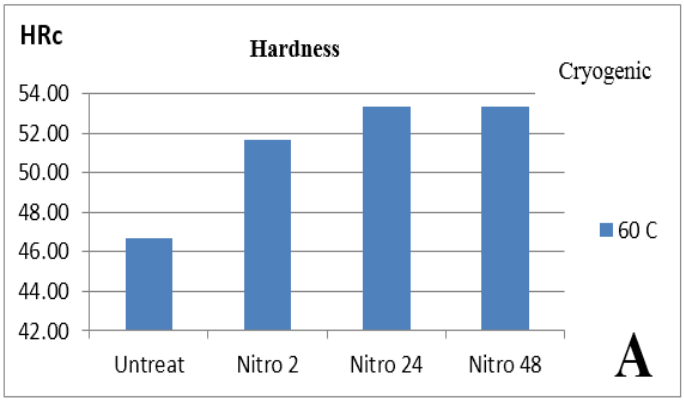

Figure 2 A. The hardness of Martemper Ductile Iron in warm water media at the temperature of 60^0C with holding time 60 second, continued with Cryogenic treatment process holding time variance in liquid nitrogen of 2 hours, 24 hours and 48 hours.

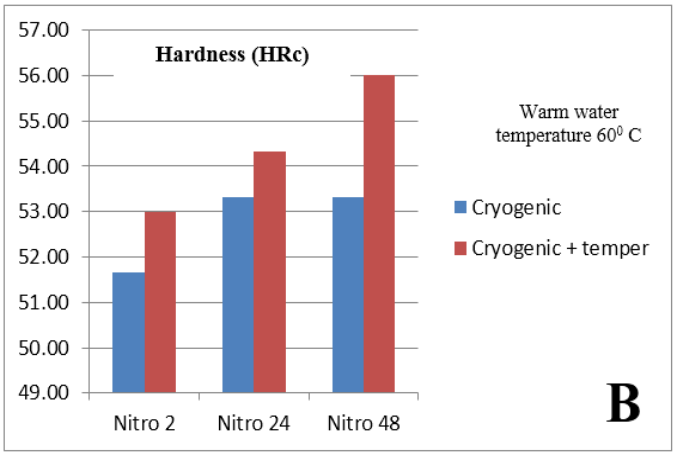

Figure 2 B. The result hardness of Cryogenic treatment process continued with 150^0 C temper for 1 hour.

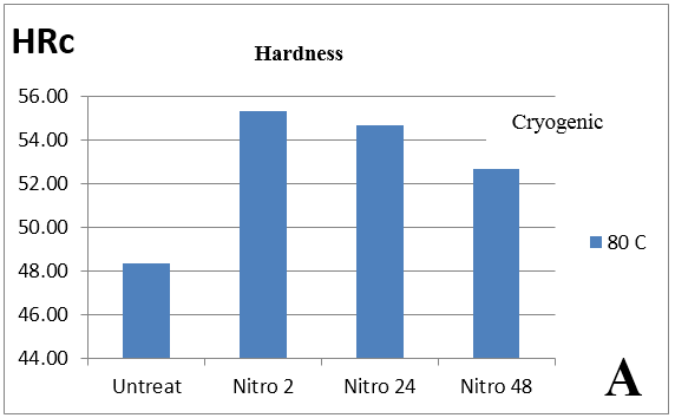

Figure 3 A. The hardness of Martemper Ductile Iron in warm water media at the temperature of 80^{0}C with holding time 60 second, continued with Cryogenic treatment process holding time variance in liquid nitrogen of 2 hours, 24 hours and 48 hours.

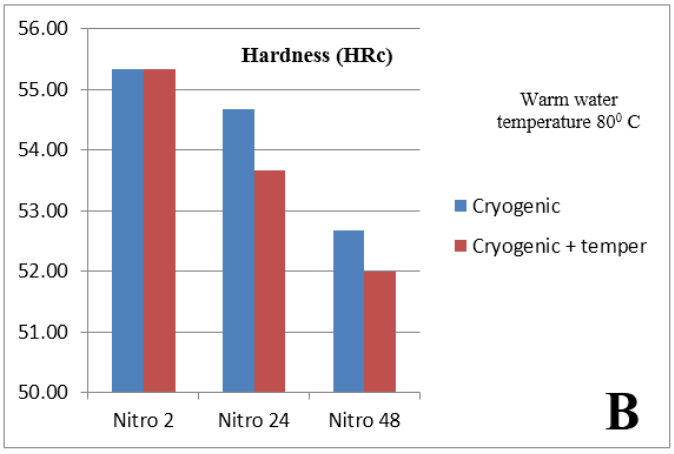

Figure 3 B: The result hardness of Cryogenic treatment process continued with 150^0 C temper for 1 hour.

Martemper process using FCD-45 material with the hardness 9 HRc. The results of Martemper process in FCD-45 with quenching in warm water with the temperature of 40^{0}C obtained hardness 51.33 HRc (see Table 1). It shows 470% increase in hardness of FCD 45 material compare with pre-treatment condition.

MDI (Martemper ductile iron) materials is processed with Cryogenic treatment, which is cooled in liquid nitrogen with a variation of holding time 2 hours, 24 hours and 48 hours, then placed in room temperature. Figure 1A shows the impact of Cryogenic treatment for increasing hardness compare with the results of martemper process. Cryogenic Treatment on Martemper material Ductile Iron (MDI) obtained the highest hardness 55.33 HRc (see Table 1), so that an increasing of hardness for 8% compare with the results of Martemper process, compare with FCD 45 with the increase of hardness by 515%. Longer holding time at Cryogenic treatment progressively increase the hardness. However, Martemper process using warm water at the temperature of 80^{0}C (see Figure 3A), then followed by Cryogenic treatment, indicates a decrease in hardness compared to warm water with the temperature of 40^{0}C and 60^{0}C (Figure 1A & 2A)

MDI materials temperature in warm air with the temperature of 40^{0}C and 60^{0}C continued to be processed with Cryogenic + temper 150^0 C for 1 hour and air-cooled, show an increase in the hardness compare with the results of Cryogenic treatment (see Table 1 and Figure 1B & 2B), while Figure 3B shows cryogenic treatment + temper result a decrease in hardness compare with the results of cryogenic treatment, which previously processed by martemper in warm water at the temperature of 80^{0}C. Longer holding time on Cryogenic treatment, higher the increase in hardness, as shown in Figure 1B and 2B. It is different Figure 3B which shows longer holding time will decrease hardness. It is due to the 80^{0}C warm water used during martemper process which is sufficient, thus the material experienced a decrease in hardness.

WEAR RESISTANCE

Table. 2 Wear resistance results of Martemper Ductile Iron process in the media of warm water with temperature variance and holding time 60 s and Cryogenic treatment and Temper

	Wear resistance		
Condition	T 40^0 C	T 60^0 C	T 80^0 C
Martemper (Cryogenic Untreatment)	3.478	1.571	3.478
Nitrogen 2 hours	3.268	1.716	0.876
Nitrogen 24 hours	6.377	6.195	3.126
Nitrogen 48 hours	6.308	3.093	1.354
Nitrogen 2 hours + Temper 150^0 C	3.301	3.299	1.320
Nitrogen 24 hours + Temper 150^0 C	6.539	6.331	2.159
Nitrogen 48 hours + Temper 150^0 C	6.601	6.601	1.683

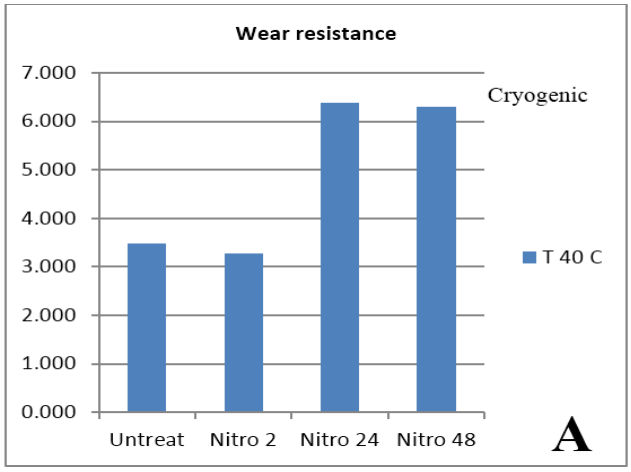

Figure 4 A. Wear resistance result of Martemper Ductile Iron in warm water media at the temperature of 40^0C with holding time 60 second, continued with Cryogenic treatment process holding time variance in liquid nitrogen of 2 hours, 24 hours and 48 hours.

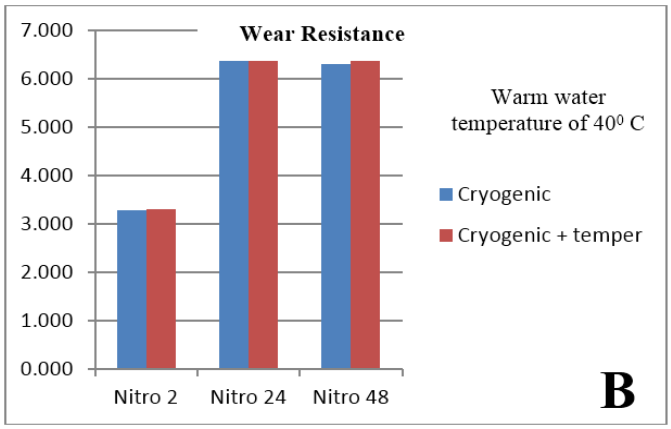

Figure 4 B. Wear resistance result of Cryogenic treatment process continued with 150^0 C temper for 1 hour.

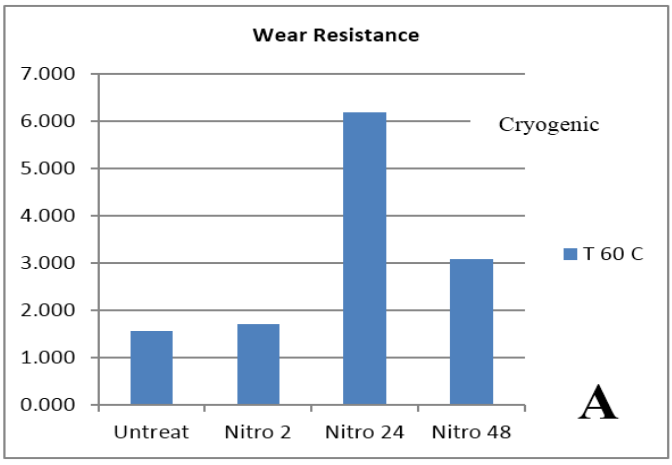

Figure 5 A. Wear resistance result of Martemper Ductile Iron in warm water media at the temperature of 60^0C with holding time 60 second, continued with Cryogenic treatment process holding time variance in liquid nitrogen of 2 hours, 24 hours and 48 hours.

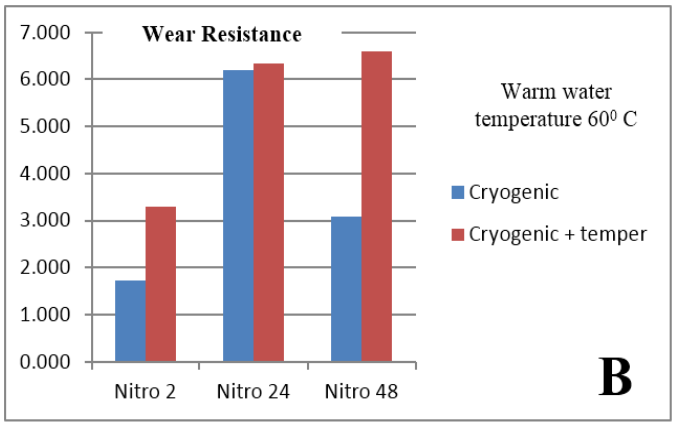

Figure 5 B. Wear resistance result of Cryogenic treatment process continued with 150^0 C temper for 1 hour.

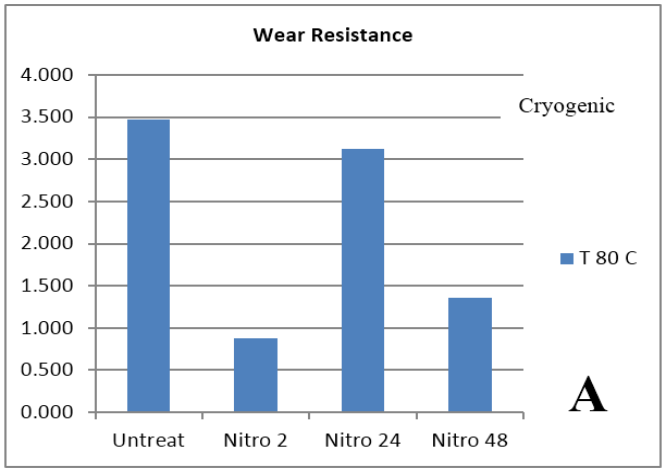

Figure 6 A. Wear resistance result of Martemper Ductile Iron in warm water media at the temperature of 80^0C with holding time 60 second, continued with Cryogenic treatment process holding time variance in liquid nitrogen of 2 hours, 24 hours and 48 hours.

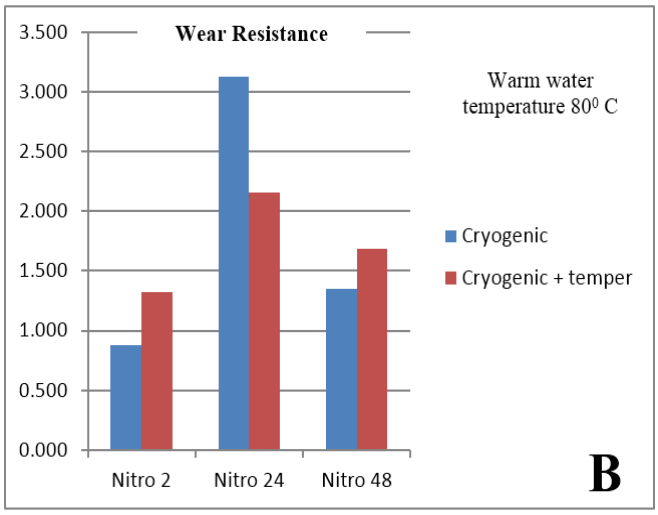

Figure 6 B. Wear resistance result of Cryogenic treatment process continued with 150^0 C temper for 1 hour.

Table 2 and Figure 4A show the influence of longer holding time (2 hours, and 24 hours) in Cryogenic treatment with prior martemper process in warm water with the temperature 40^0C with holding time t 60 second**,** resulting to the increase of ware resistance. However, 48 hours holding time in Cryogenic treatment cause decrease in ware resistance. It is similar with the result of Cryogenic treatment on MDI material in warm water with the temperature 60^0C (Figure 5A). It contrasts with warm water with the temperature 80^0C, as the ware resistance is decreased.

It is supported with the hardness result shown in Figure 1, increase in hardness is followed by higher wear resistance. Observed from the effect of warm water temperature during martemper process (40^0C, 60^0C, and 80^0C), continued with Cryogenic treatment, it shows decrease in wear resistance (Table 2 and Figure 4 - 6).

Wear resistance result of Temper under temperature of 150^0C with holding time 1 hour and cooled down in the air. The previous material is treated by Martemper with the warm water media with the temperature of 40^0C with holding time 60 second, then continued to Cryogenic treatment with holding time variance of 2 hours, 24 hours and 48 hours, show an increase of 3.5% in wear resistance compare to Cryogenic treatment result (see Figure 4B). The effect of warm water temperature is stronger at martemper process, as the ware resistance is decreased (see Figure 4A, 5A and 6A). Figure 5B and 6B show that ware resistance result of temper process is higher compare to Cryogenic treatment result with holding time variations of 2 hours, 24 hours, and 48 hours. However, Figure 6 shows the result of Cryogenic treatment with holding time 24 hours, with the higher ware resistance compare to temper process.

The highest wear resistance of Martemper process on the FCD-45 material with quenching in warm water reached 1/K= 3.478 (see Table 2). The highest wear resistance result of Cryogenic Treatment on Martemper Ductile Iron (MDI) material is 1/K= 6.377 (see Table 2), indicating an increase in wear resistance of 83%. It is in accordance with the research by Suprapto A, et al., (2016) which shows the decrease of wear resistance for 77% as the result of Cryogenic Treatment on ADI (Austemper Ductile Iron). The highest wear resistance of temper is 1/K= 6.601 (see Table 2), showing an increase in wear resistance for 3.5% compare to Cryogenic Treatment result.

CONCLUSION

1. The hardness result produced by Martemper is HRc 51.33, Cryogenic Treatment resulted with HRc 55.33, and Temper process reached HRc 56.00; indicating an increase in hardness.
2. Results of Cryogenic Treatment show an increase of 83% in wear resistance compare to Martemper process result.
3. Temper results show an increase of 3,5% in wear resistance compare to Cryogenic Treatment.

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