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# Effects of Heat Treatment on the Mechanical Properties of the Vanadis 4 Extra and Vanadis 10 Tool Steels

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# Abstract

Vanadis tool steels which are a trademark of the Uddeholm AB Company are high vanadium content (along with chromium and molybdenum) steels with unique mechanical properties such as very high wear resistance along with a good machinability, dimensional stability and grind ability. They are widely used in blanking operations, stamping, and deep drawing, cutting and slitting blades. Microstructural features of Vanadis steels are directly depended upon the distribution of the carbide grains. Based upon the carbon and vanadium contents of the Vanadis tool steels, wear test results and micro hardness values are correlated with the resulting microstructural features.

Keywords: Tool steels; Vanadis; Powder metallurgy; Wear resistance

### Introduction

Vanadis tool steels which are a trademark of Uddeholm Company are high vanadium content (along with chromium and molybdenum) steels with unique mechanical properties such as very high wear resistance along with a good machinability, dimensional stability and grind ability. Vanadis steels are manufactured using powder metallurgical routes and they offer a combination of high wear resistance, high hardness and good toughness [1]. Vanadis tool steels have a very homogeneous microstructure and highly refined grain distribution compared to other conventional steels. Based on such characteristics, they are widely used in blanking operations, stamping, and deep drawing, cutting and slitting blades [1,2].

Microstructural features of Vanadis steels are directly depended upon the type of carbides and the matrix phase. The distribution and the size of carbides as eutectic and secondary carbides effect the tool performance and tool life. In this regard, the conditions of heat treatment have a determining impact on such demanding properties. Undissolved carbide grains have also unique effect on the wear resistance due to inhibiting role on the coarsening of the austenite grains.

It is reported that there are two major types of carbides in Vanadis steel following austenitizing, i.e.,  $M_7C_3$  secondary carbides (dissolved in the austenite) and eutectic MC carbides (stable up to 1150°C along with small spherical carbides as alloyed cementite [2,3]. Laser hardening method is another technique to improve the properties of such tool steels [4,5].

In this study, the effect of heat treatment on the Vanadis 4 extra and Vanadis 10 grade tool steels are investigated. Following the annealing and quenching cycles on the steel samples, abrasive wear behavior, microstructural changes and micro hardness were determined. Based upon the carbon and vanadium contents of the Vanadis tool steels, wear test results and micro hardness values are correlated with the resulting microstructural features [6].

# **Material and Methods**

Vanadis steel parts were provided by Uddeholm Company. Steel samples were machined properly to shape them into cylindrical forms for wear tests. Each specimen machined properly and reduced diameters till fit the pin on disc sample attached. Lengths have reduced enough approximately 15-25 mm and diameters reduced 4, 5-7, 5 mm after machining. Thereafter, the Vanadis 4 extra samples were annealed at 1000°C for 9 minutes and Vanadis 10 at 800°C for 5 minutes and quenched into water at room temperature (heat treatment procedure was selected according to Uddeholm AB Materials Safety Data Sheet). All the measurements were determined on both as-received (witness samples) and heat treated samples. Chemical compositions of the samples of Vanadis 4 extra and Vanadis 10 manufactured with powder metallurgical routes are shown in Table 1.

# Wear tests

Wear tests were conducted on the as-received and heat treated samples using the Pin-On-Disk (POD) wear test rigs. AISI H13 steel disc is used as the sliding platform for wearing under dry conditions. The steel disc is also heat treated and has the hardness value of 36.3 Rockwell HRC. 20 N loads are applied for Vanadis 4 extra samples and 10 N loads are applied for Vanadis 10 samples.

In all the tests, sliding diameter, the rate and the duration of tests were about 140 mm, 3000 rev/min and 10, 20, 30, 40, 50 and 60 min period of time respectively. Weights of the specimens before and after the wear tests were measured by an electronic balance which has  $(\pm 0.1 \text{ mg})$  sensitivity to determine the weight loss and consequently the wear rates.

#### Micro hardness tests

Vickers micro hardness values for both as-received and heat treated samples were determined using a Vickers micro hardness testing unit HV 0.2. Average values of five measurements were recorded.

Steel	С	Si	Mn	Cr	Мо	v	Fe
Vanadis 4	1.4	0.4	0.4	4.7	1.5	3.7	Balance
Vanadis 10	2.9	0.5	0.5	8	1.5	9.8	Balance

Table 1: Chemical composition of the samples in mass fractions (wt%).

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#### Microstructural investigation

Microstructural analysis of the samples of the Vanadis 4 extra and Vanadis 10 both untreated and heat treated were conducted using a scanning electron microscope, SEM Philips XL 30 SFEG with resolution 1.5 nm at 10 kV. Standard metallographic sample preparation route (grinding, polishing, fine polishing and etching) was used to prepare the samples for SEM analysis.

#### Results

Weight loss (in mg) vs. time (in min.) graph is shown in Figures 1 and 2 demonstrating the effect of heat treatment on the wear resistance which shows approximately average 54% and 76% decrease in weight loss in 40 min for the heat treated Vanadis 4 extra and Vanadis 10 samples respectively. It should be noted that the wear loss data demonstrates significant decrease in weight loss after 40 and 50 min due to strain hardening effect in between the surfaces of Vanadis samples and AISI H13 steel disc.

Table 2 shows the results of these measurements.

Micro hardness values tabulated in Table 2. Indicate more than 160% increase in micro hardness in Vanadis 4 samples while Vanadis 10 as-received and heat-treated samples show only a slight and insignificant increase in micro hardness values.

#### Discussion

SEM micrographs of the Vanadis 10 samples both in untreated and heat treated conditions are shown in Figures 2 and 3. Figures 3







Vanadis	s 4 extra	Vanadis 10		
As received	Heat Treated	As received	Heat treated	
278.7 ± 15.5	728.4 ± 7.5	313.6 ± 6.5	315 ± 6.2	

Table 2: The results of microhardness measurements, HV 0.2.

and 4 illustrate the microstructures of the as-received and heat treated Vanadis 4 extra and Vanadis 10. As can be seen in Figures 3b and 4b, the as-received structures of Vanadis 4 extra and Vanadis 10 consist of carbide grains (eutectic carbides, MC and secondary carbides,  $M_{7}C_{3}$  and other finer grain size carbides) embedded in a ferrite matrix. MC type carbides appear darker since they contain higher amount of carbon while other carbides reveal brighter appearance due to less amount of carbon and more iron, chromium (6). Figures 4a and 4b show no hardening effects in the microstructures as in the case of micro hardness data of the Vanadis 10 samples given in Table 2. Micrographs of these samples reveal no quenching structures meaning that no carbide grains are dissolved. However, in the Vanadis 10 microstructure, larger size grains are noticeable and following the heat treatment some grain growth can be seen. Such a grain growth mechanism could lead much higher wear resistance after the heat treatment.



Figure 3a: SEM Micrographs of the Vanadis 4 extra samples (×5000 mag.); (left) heat treated; (right) untreated.



Figure 3b: SEM Micrographs of the Vanadis 4 extra samples (×20000 mag.); (left) heat treated; (right) untreated.



Figure 4a: SEM Micrographs of the Vanadis 10 samples (×5000 mag.); (left) heat treated; (right) untreated.



Figure 4b: SEM Micrographs of the Vanadis 10 samples (×20 000 mag.); (left) heat treated; (right) untreated.

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On the other hand, there can be seen considerable changes in the microstructures of the Vanadis 4 extra samples with heat treatment (Figures 3a and 3b). In this microstructure, secondary carbides,  $M_2C_3$  are dissolved in austenite while MC type carbide grains are still stably distributed in the matrix. Characteristic martensitic needle-like structure and retained austenite can be observed in the Figure 3b micrograph along with dissolved carbide grains in ferrite matrix. A distinct increase in the micro hardness values (app. 161% increase following the heat treatment) is given in Table 2 for the Vanadis 4 extra while only a very slight increase in the Vanadis 10 is recorded. Weight loss data in Figure 1 also support such a drastic micro hardness increase.

# Conclusion

- The inhomogeneous microstructure of the Vanadis 4 extra which consists of needle-like marten site, carbide grains and most probably retained austenite forms following the heat treatment. A distinct increase in micro hardness values and considerable increase in wear resistance would be the results of such microstructural formation.
- Considerable increase in wear resistance of the heat treated Vanadis 10 would be due to grain growth of carbide grains embedded in the ferrite matrix. Larger size carbide grains may

have an inhibiting role against the wear mechanism in between the surfaces of Vanadis 10 samples and AISI H13 steel disc.

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#### References

- 1. Uddeholm AB (2013) Uddeholm Vanadis 10 Superclean.
- Sobotova J, Jurci P, Adamek J, Salabova P, Prikner O, et al. (2013) Diagnostics of the Microstructural Changes in Sub-zero Processed Vanadis 6 P/M Ledeburitic Tool Steel. Materials and Technology 47: 93-98.
- Ocak M (2015) An Investigation On Mechanical And Microstructural Property Changes, Due To Different Heat Treatment, of Vanadis 4 Cold Work Tool Steel Produced By Powder Metallurgy. (Doctoral dissertation, Fen Bilimleri Enstitüsü).
- 4. Surzhenkov A, Kulu P, Viljus M, Vallikivi A, Latokartano J (2010) Microstructure and wear resistance of the laser hardened pm tool steel vanadis 6. In Proceedings of the International Conference of DAAAM Baltic Industrial Engineering.
- 5. Köse G, Mutlu Z (2015) Laser hardening of tools steels. Doğuş University.
- Jurči P, Dománková M, Ptačinová J, Hudáková M (2015) Phase constitution of sub-zero treated Vanadis 6 tool steel. Metal 2015, Jun 3rd-5th, Brno, Czech Republic, EU.