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1000°C Brinell Hardness
with Nanovea T2000 Tribometer

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INTRO

Material properties, such as reactivity and strength, can drastically change at higher temperatures. This makes high temperature applications, (e.g. jet engines, fabrication chamber material, and even cookware) require careful material selection. Thus, it is important to understand how materials behave in different temperature conditions. The strength of a material can be measured by using the Nanovea T2000 Tribometer. To demonstrate this, a steel sample was used to conduct Brinell hardness testing from temperatures ranging from 25°C to 925°C.

IMPORTANCE OF HIGH TEMPERATURE HARDNESS TESTING

Hardness is a mechanical property of materials that characterizes its performance under stress. Higher hardness values mean that the material will deform less. It is well-known that certain materials will behave a certain way at room temperature (e.g. metals are hard and polymers are soft). At high temperatures, however, the mechanical properties of the material will change and even metal can have softer behavior. For a material to fit high temperature applications, it is critical to fully understand their mechanical limits.

MEASUREMENT OBJECTIVE

Using a 10mm tungsten carbide (WC) ball, a load of 1000N (~100kgf) was applied to a steel sample at 25, 200, 400, 600, 800, and 925°C. The resulting indentation was measured using Nanovea's 3D Line Sensor to obtain its diameter.

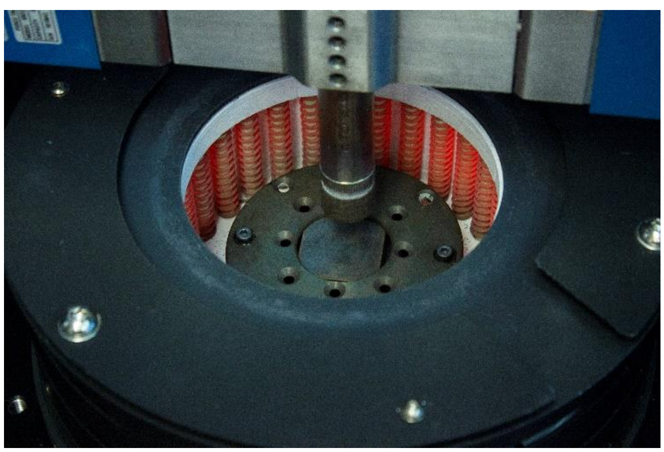


Figure 1: Sample mounted in the high temperature oven under the T2000 Tribometer

TEST PROCEDURE

Table 1: Test parameters for high temperature hardness testing

Test Parameters	
Temperature (°C)	25, 200, 400, 600, 800, 925
Test Force	1000N (~100kgf)
Force-Diameter Ratio	1
Ball Material	Tungsten Carbide (WC)
Ball Diameter	10mm

RESULTS AND DISCUSSION

The following equation was used to calculate the Brinell hardness:

$$= \frac{2F_{kgf}}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

Where F_{kgf} is the force applied, D is the diameter of the ball, and d is the diameter of the indentation. Two diameters were measured per indent and the values were averaged to obtain d.

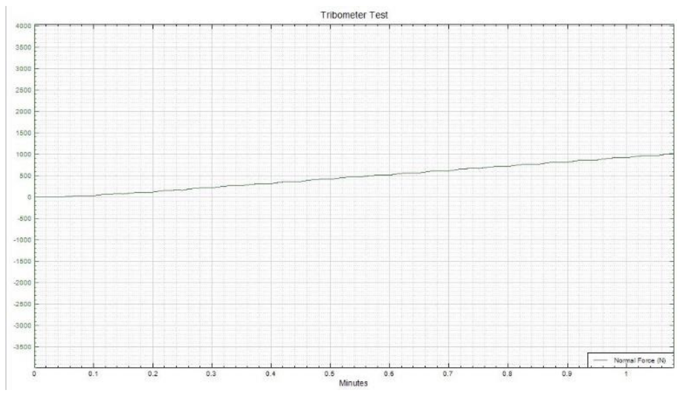
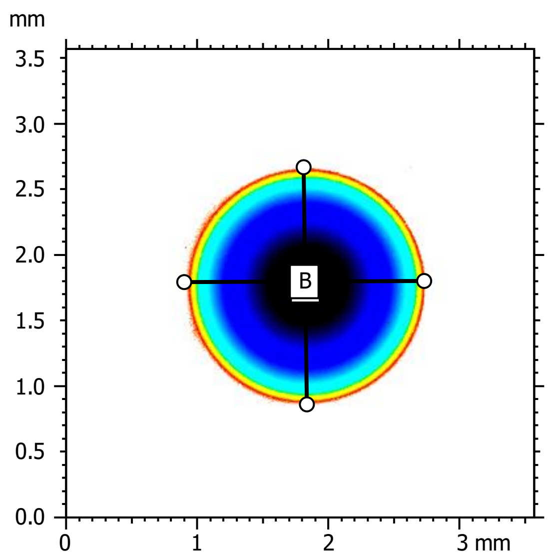


Figure 2: Loading curve of indentations – Load vs Time



Distances	Unit	A	B	
HDist	mm	1.807	1.830	

Figure 3: Diameter measurement of indentation at 800°C

Table 2: Summary of Results

Temperature (°C)	Diameter 1 (mm)	Diameter 2 (mm)	Average Diameter (mm)	HBW (10/100)
25	1.153	1.145	1.149	96.12
200	1.150	1.201	1.176	91.82
400	1.165	1.261	1.213	86.21
600	1.265	1.258	1.262	79.69
800	1.807	1.830	1.819	38.18
925	2.858	2.833	2.846	15.40

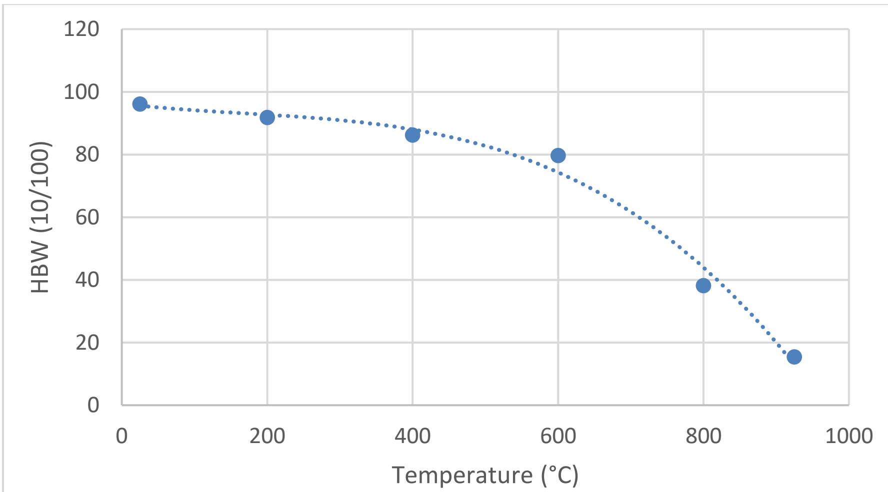


Figure 4: Graph of hardness vs. temperature

From the results, it appears the steel gradually loses strength up until approximately 600°C. From 600°C onwards, steel begins to quickly lose its strength. The steel sample lost 84% of its hardness between room temperature and 925°C.

CONCLUSION

While there are many technical aspects that needs to be considered when conducting high temperature testing, the Nanovea T2000 Tribometer is able to conduct tests up to 1200°C with a 2000N load. To demonstrate this, Brinell hardness tests were conducted on a steel sample from 25°C to 925°C. The steel sample was indented at increasing temperature to map its hardness with temperature. The indents were profiled with Nanovea's Line Sensor to obtain its diameter. The hardness was observed to slowly decrease with rising temperature, then dramatically drop past 600°C. Due to the large difference in hardness between at room temperature and high temperature, a force-diameter ratio of 5 or 10 should be used at lower temperature. The force-diameter ratio of 1 is ideal above 900°C.

Learn more about Nanovea Tribometers or Lab Services