Next Generation Alloy Development for Scanning Induction Hardened Bearings

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The base steel material received additions of vanadium in both castings, and silicon in one casting. After samples were prepared, hardness, toughness, and compressive strength were tested for each material after a heat treatment replicating Timken’s process. Multiple pictures were taken of the microstructure in order to better understand the properties of the material. The material with vanadium and silicon additions recorded slightly higher in hardness and toughness testing compared to the material with only vanadium. Vanadium-silicon steel also compares well to the original steel (Timken 4150). Toughness tested similar to Timken 4150, and the hardness is improved for the new material. Compression test results are pending.

**Introduction and Results**

Timken, a bearing manufacturer, is having trouble with roller bearings scratching the inner and outer rings on their wind turbine bearings. The more the rings get scratched, the less efficient the windmills become. The objective of this project is to test the additions of different elements and their effect on the hardenability, toughness, and compressive strength of Timken 4150 steel. Hardenability refers to how hard the material can become through heat treatments. It is the most important property for this experiment since a higher hardness will result in a higher resistance to scratching. Toughness and strength are also tested because the bearings need to be able to sustain more stresses due to their large size.

Metals often have additives during the casting process that refine the steel’s microstructure and manipulate its properties. Alloying can help strengthen or weaken a metal’s properties according to material used as an additive. In this experiment, vanadium and silicon are added to Timken 4150 in order to improve the steel’s hardenability, strength, and toughness. The base steel with only vanadium is also tested in order to clearly tell how each additive affects the material.

A Y-block was cast in the foundry for each steel to provide material for testing. The casting process involves creating a mold using green sand, melting the steel, adding the necessary carbides, and pouring the liquid metal into the mold. The block is then cut using a band saw and then milled down to a one inch by two inches by three inches block with a chamfer on one end.

A chamfered block was hot rolled for each material. Hot rolling is a process where a block of metal is heated
above its recrystallization temperature and then compressed between two rollers through multiple passes. The chamfer on the block allows the rollers to grab the block and pull it through the system. Since the block is heated above the recrystallization temperature, it resets the microstructure, is more ductile, and is therefore easier to manipulate. Timken uses a forging and hot rolling process to form their bearings, but forging is impractical with the equipment provided and size of the samples.

After hot rolling, the material was processed into charpy samples. This was done by milling and surface grinding the slab to 10mm thickness. Eight 10mm by 10mm rectangular prisms were cut out of the slab using a waterjet. A notch is cut in the exact center of the sample so the sample will break in the same place every time. Charpy testing consists of a large hammer swinging from a fixed distance and breaking a sample at the bottom of the swing. Each sample has the exact same dimensions and are placed in the exact same spot for data accuracy. The measurement for toughness is the force absorbed by the sample in joules as recorded by the machine.

The steel with vanadium and silicon additives recorded slightly higher values for toughness compared to the steel with only vanadium added. When the test hammer hit the vanadium-silicon samples, they recorded an average of 14 joules of energy absorbed while the vanadium samples recorded an average of 12 joules of energy absorbed. These values are similar to the Timken 4150 steel which recorded between 10-17 joules. The base material had no issues with toughness, so the new material meets specification.

For hardness and compression testing, multiple bars were cut from the cast block using a band saw and mill. The bars were then shaped into 8mm thick rods using a lathe then sectioned into 10mm tall samples. Timken passes an induction coil along the perimeter of their bearing rings, so this was simulated using an induction coil to quickly heat the samples to 1000 degrees Celsius for either one, five, or ten seconds, then cooled at a rate of five degrees Celsius per second. The samples were then tempered for one hour at 180 degrees Celsius.

Compression testing is done by placing a small cylindrical sample (10mm tall and 8mm wide) on a load frame. The load frame exerts 100 kN of force to compress the sample. Exact measurements of the sample are taken before and after the testing, and the measurements are used to calculate the compressive strength of the material. The calculations for the compression
testing are currently pending but the samples were hardly reduced in height which points to a very high compressive strength.

The Rockwell test measures hardness by pressing standardized tip called the indenter into the surface of the sample being tested. The device measures the depth of the indenter’s penetration and calculates a hardness value accordingly. The indenter used an HRC standard diamond tip for the experiment due to the high hardness of the material being tested.

Vanadium-silicon steel tested a total average of 56.3 HRC after heat treatments. The samples with a ten second heat treatment averaged 56.9 HRC, 55.7 HRC for the five second treatment, and 56.6 HRC for the one second hold. Although these are high values, there are no measurements from Timken 4150 to compare them to. A Jominy test had already been executed for both vanadium-silicon and Timken 4150 where hardness was measured. The Jominy test involves a bar of four inches long by one inch radius that is heated to austenitic temperature before a jet of water quenches the metal from one end. This details how the material is affected by different cooling rates since one end of the bar is cooled much faster than the other end. Each bar was heated to 900 degrees Celsius for one hour before the test was performed with water at 23 degrees Celsius.

Hardness measurements after the Jominy test revealed higher hardness for vanadium-silicon steel than the Timken 4150. Jominy position 30 is the focus of the Jominy test because that represents a cooling rate of about five degrees Celsius. The vanadium-silicon steel recorded approximately 5 HRC higher than Timken 4150 for the Jominy test. Vanadium-silicon recorded lower when heat treated with the induction coil because the Jominy test is heat treated for one hour compared to a few seconds on the induction coil. The Jominy test is less accurate but shows a difference between vanadium-silicon and Timken 4150. Even using the induction heating process, the vanadium-silicon still produced higher hardness of 56.3 HRC than the original material on a Jominy test at 55 HRC.
The vanadium-silicon steel provides an adequate upgrade over the Timken 4150 in terms of mechanical properties. Hardness is improved over the original steel by a difference of 5 HRC after Jominy tests. The difference between 55 and 60 HRC is not insignificant as that is a very hard material. Toughness is not an issue for the new material because it falls in the same range as Timken 4150. Compressive strength has not yet been determined but the lack of height difference from before and after testing is promising for the material’s strength.

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References

