VBN Components AB

3D printed metals with unique wear resistance

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Materials development for additive manufacturing

Development of NEW METAL MATERIALS and PROCESSES for suitable 3D-printing methods.

Commercialization of wear resistant components made with Vibenite® materials.

Manufacturing according to customer CAD-drawing of:
- A) hardened near-net-shape blanks
- or
- B) finished components (by grinding or edm)

Max size: 200 x 200 x approx. 380 mm (today).
Gear cutting hob in Vibenite® 280 - before and after grinding
The Vibenite® material group

Vibenite® 480
Hybrid carbide metal
~65% carbides
Hardness of ~66 HRC

2017

Vibenite® 290
World’s hardest steel
~25% carbides
Hardness of 68-72 HRC

2017

Vibenite® 280
~20% carbides
Hardness of 63-70 HRC

2013

Vibenite® 350
Corrosion resistant
~20% carbides and nitrides
Hardness of ~60 HRC

2017

Vibenite® 150
~7% carbides
Hardness of 55-63 HRC

2016

Vibenite® 150
Corrosion resistant
~20% carbides and nitrides
Hardness of ~60 HRC

2016

Vibenite® 480
Hybrid carbide metal
~65% carbides
Hardness of ~66 HRC

2017
Why 3D-printing of wear resistant metals?

Traditional manufacturing

- Powder
- HIP
- Heating
- Forging
- Rolling
- Annealing
- Oxide scale removal
- Hot rolling
- Tempering
- Drawing
- Straightening
- Grinding
- Transportation
- Warehouse bar/rod stock
- Cutting
- Turning
- Milling
- Heat treatment
- Grinding
  + a lot of smaller operations
  + a lot of stop times
  + a lot of intermediate storages
  = Finished component

VBN Components manufacturing

- Powder
- Additive manufacturing
- Heat treatment
- Grinding
  = Finished component

Shaper cutter in Vibenite® 280 Optimum 70
Material with hardness and wear resistance

- **Vibenite® 350** - Stainless for plastic processing tools, pumps, rings, valves, etc.

- **Vibenite® 150** - Tough alloy for functional prototypes, tools, etc.

- **Vibenite® 480** - Hybrid carbide (cemented carbide) with ~65% carbide content. Hard, heat and wear resistant.

- **Vibenite® 280** - Metal cutting tools, wear protection, fatigue resistance, etc. Excellent combination of high hardness and toughness.

- **Vibenite® 290** - *The world’s hardest steel*, for metal cutting tools, dry machining tools, etc.
Application examples

Metal cutting tools

Tools for food industry

Drills

Erosion components
Pumps, valves, seats
Wood working tools
High performance components
Plastic Processing Tools
High temperature wear etc

Engine components

Mining and rock drilling tools
Vibenite® in comparison with other additively manufactured materials

Vibenite® is in its own division of hard materials. It is the only AM material with carbide content.

Source: EPMA 2017, 2nd ed, Introduction to Additive Manufacturing Technology, sec 3.4.1 [Hardness and Yield strength for various materials produced by powder bed additive manufacturing technologies (Courtesy of Fraunhofer IFAM)], "(1)"=different manufactures; VBN Components AB 2018.
VBN Components offers

**Pre-study**
- Is Vibenite® the perfect choice for the application?
- Wear analysis
- Technical discussions
- Drawing
- First test product
- Visit in Uppsala, Sweden

**Production development project**
- Several test builds
- Adjust building parameters
- Optimal build file
- Small serial production - Serial production at VBN

**AM utilise study**
- Optimization of the function with the help of AM-technology
- First serial production
- If customer cannot produce

**License solution – Serial production at customer**
- Settings for production
- Machine recommendations
- IP rights
- Powders
VBN business model

1. First stage - test period
2. First serial production
3. License solutions - at customer plant

- Functional prototypes
- First series
- Test details
- Small series production
- Production solutions
Vibenite® 350

- Very wear resistant and stainless material. ~60 HRC.
- Fine microstructure with fine carbides in a chromium rich martensitic stainless matrix => excellent properties.
- Developed with support from the Swedish Energy Agency => large energy and material savings.
- Applications: Valves, pumps, turbines, marine applications, plastic processing tools, etc.

Microstructure (hardened)

<table>
<thead>
<tr>
<th>C</th>
<th>Cr</th>
<th>Mo</th>
<th>V</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9</td>
<td>20</td>
<td>1.0</td>
<td>4.0</td>
<td>Bal</td>
</tr>
</tbody>
</table>

Composition
Vibenite® 150

- High performance, wear resistant Multi-Purpose material.
- Hardness 55 - 64 HRC.
- Fine microstructure with fine and wear resistant carbides -> unique combination of toughness and wear resistance.
- Functional prototypes, tool holders, cold work applications

<table>
<thead>
<tr>
<th>Composition</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>1.5</td>
</tr>
<tr>
<td>Cr</td>
<td>4.0</td>
</tr>
<tr>
<td>Mo</td>
<td>2.5</td>
</tr>
<tr>
<td>W</td>
<td>2.5</td>
</tr>
<tr>
<td>V</td>
<td>4.0</td>
</tr>
<tr>
<td>Fe</td>
<td>Bal</td>
</tr>
</tbody>
</table>

Hardening temp (°C) | Hardness (HRC)
---|---
950 | 52
1000 | 54
1050 | 56
1100 | 58
1180 | 64

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Vibenite® 280

• High strength, high hardness and very high wear resistance.

• Fine microstructure with high volume of fine carbides => high toughness.

• High hot hardness and uniformity.

• Wear parts and cutting tools such as gear hobs, broaches, cutters, etc.

<table>
<thead>
<tr>
<th>Fe</th>
<th>C</th>
<th>Cr</th>
<th>Mo</th>
<th>W</th>
<th>Co</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bal.</td>
<td>2,30</td>
<td>4,2</td>
<td>7,0</td>
<td>6,5</td>
<td>10,5</td>
<td>6,5</td>
</tr>
</tbody>
</table>

Composition

Hardness HRC

Hardness HRC (1) 63-70 HRC

(1) = Depends on hardening temperature, see graph.
Vibenite® 290

- The world’s hardest commercially available steel grade. Released November 2017. Possible to harden 68-72 HRC.

- Fine microstructure with high volume (~25vol%) of very fine carbides.

- Extremely high hot hardness and uniformity.

- Can replace cemented carbides in several applications.

- Wear parts and cutting tools such as gear hobs, broaches, shaper cutters, power skiving wheels, etc.

### Microstructure (hardened at 1180°C)

<table>
<thead>
<tr>
<th>Fe</th>
<th>C</th>
<th>Cr</th>
<th>Mo</th>
<th>W</th>
<th>Co</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bal.</td>
<td>2.5</td>
<td>4.0</td>
<td>5.0</td>
<td>11.2</td>
<td>16</td>
<td>6.3</td>
</tr>
</tbody>
</table>

Composition
In December 2018, VBN launched Vibenite® 480.

The world’s first commercial, 3D printed cemented carbide (patented).

Hardness 800-900 HV with ~65% of carbides.

Extremely high production yield and wear resistance.

This new group of materials is called Hybrid Carbides, since it combines toughness from high speed steels and high hot hardness from carbides. It does not require binders and sintering and is therefore not “cemented”, which avoids typical limitations.

<table>
<thead>
<tr>
<th>C</th>
<th>Cr</th>
<th>W</th>
<th>Co</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.6</td>
<td>20.5</td>
<td>22.5</td>
<td>Bal</td>
</tr>
</tbody>
</table>
Abrasive resistance of Vibenite® 480

<table>
<thead>
<tr>
<th>Material</th>
<th>Measured hardness HV</th>
<th>Carbide content [%]</th>
<th>Wear volume $10^{-3}$ mm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibenite 480</td>
<td>835</td>
<td>65</td>
<td>5.2</td>
</tr>
<tr>
<td>Cemented carbide 6% Co medium grain size</td>
<td>1490</td>
<td>94</td>
<td>7.1</td>
</tr>
<tr>
<td>Cemented carbide 25% Co medium grain size</td>
<td>955</td>
<td>75</td>
<td>9.8</td>
</tr>
</tbody>
</table>

- The test resulted in chipping wear of traditional cemented carbides.
- Extremely low wear rate of Vibenite® 480
- Hardness is not everything, the correct balance between abrasive particle type/size and material choice is important.

Abrasive test – dimple grinder
Diamond slurry, 2.5µm particles

Vibenite® Combo

• Method developed in 2019.
• Combining different properties in the same component.
• Vibenite® 290 printed upon cylinder of Vibenite® 150.
• Toughness of Vibenite® 150 combined with the extreme hardness of Vibenite® 290, the world's hardest steel.
• Control of thermal expansions ensures pore- and crack-free weld.
• Many possibilities exists
Metal cutting

Comparison of Vibenite® 280 gear hob with standard competitor hob

Analyzed scenarios of gear-cutting tools at large Swedish manufacturer

Results of Life Cycle Cost Analysis (LCCA) for gear cutting (20,000 units per year):

• Total production cost per produced gear reduced by 15-20% due to double lifetime of the Vibenite® tool.

• Double cutting feed cuts cost by an additional 15-20%.

• Total reduced production cost per produced gear = 30-40%.
Heavy material savings on gear hobs

Case calculated on Vibenite® 280 (before launching Vibenite® 290 and 480).

<table>
<thead>
<tr>
<th></th>
<th>Yield traditional manufacturing</th>
<th>Yield VBN Additive Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing of steel bar</td>
<td>~70%</td>
<td>~98%</td>
</tr>
<tr>
<td>Manufacturing of hob blank</td>
<td>~50%</td>
<td>~98%</td>
</tr>
<tr>
<td>Total material yield</td>
<td>~35%</td>
<td>~98%</td>
</tr>
<tr>
<td>manufacturing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Traditional manufacturing</th>
<th>VBN Additive manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield manufacturing</td>
<td>35%</td>
<td>98%</td>
</tr>
<tr>
<td>Performance (feed)</td>
<td>100%</td>
<td>200%</td>
</tr>
<tr>
<td>Weight hob</td>
<td>15.3 kg</td>
<td>11.2 kg</td>
</tr>
<tr>
<td>Number of produced gears</td>
<td>7150 pc.</td>
<td>14300 pc.</td>
</tr>
<tr>
<td>Number of produced gears</td>
<td>7150 pc.</td>
<td>14300 pc.</td>
</tr>
<tr>
<td>hob</td>
<td>7150 pc.</td>
<td>14300 pc.</td>
</tr>
<tr>
<td>produced gear (HMCPPG)</td>
<td>6.1 g</td>
<td>0.80 g</td>
</tr>
</tbody>
</table>

=> 87% material savings!

- The first grinding removes more material from the 3D-printed part, but the following grindings are the same.
- The material savings on coatings are not included.
- The traditional example is calculated for a steel bar close in dimension, but typically larger bars are used with more material removed.
Vibenite® 290 against rock
CPOD (Crushing Pin On Disc), Kuru granite, Abrasion.

- The CPOD method is very tough for hard materials such as Vibenite® 290, since it will expose them to two-body abrasion, which abrades more than three-body abrasion.
- Still, hardened Vibenite® 290 is only worn 25% compared to the closest competitor.
- No chipping or cracks could be seen for Vibenite® 290.
Vibenite® 290, High Speed Slurry Pot Test
Kuru granite, no water. Erosion/abrasion against rock.

- The hardened Vibenite® 290 is worn only 50% compared to the closest competitor.
- No chipping or cracks could be seen.

1000 rpm -> 10m/s at tip, 20 min. test time, pin position switched each 5 min. 2 tests.
A large number of Customer benefits

• No forging, no rolling, no machining
• Possible to use extremely wear resistant materials without limitations
• Rapid product development
• New functions through intelligent geometries
• Reduced production cost with Vibenite® performance
• Heavily reduced environmental impact
• Small or large series
• Minimized material stock
• Spare parts of your choice
Get more information

YouTube:
There are also links to the films on www.vbncomponents.com

Vibenite® 480: A new type of cemented carbide
World’s hardest steel - made in Uppsala, Sweden