High Speed Steel

Abstract: The present invention relates to a low alloyed high speed steel containing in weight-%: C 0.8-1.2 %, N 0-0.2 %, Cr 2-6 %, Mo 3-5 %, W 0-1.2 %, V 0-3 %, Nb 0-2 %, Si 0.7-1.7 %, balance Fe and normal occurring impurities, wherein Mo + Si < 6 in weight-%.
5 **HIGH SPEED STEEL**

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a high speed steel, a use of such a high speed steel, a tool for hot working or chip cutting, machining or cold working, or an advanced machine element as well as a process for producing a tool blank to be used for manufacturing a tool of such a low alloyed high speed steel.

BACKGROUND OF THE INVENTION AND PRIOR ART

High speed steels (HSS) are steels being used especially in tools for different types of machining, such as drilling, milling and sawing, but other applications are also conceivable, such as for example in tools for hot-working, such as dies for extrusion of aluminium profiles and rollers for hot-rolling, in advanced machine elements and press rollers, i.e. tools for stamping of patterns or profiles in metals etc. Another application of such steels is in cold-working tools.

Important properties of such a high speed steel are a high hardness and wear or abrasive resistance as well as an easiness to be machined after soft annealing for manufacturing tools out of tool blanks of such a steel. A further property often required is a good grindability.

Different alloying elements, such as Mo, W, V and Nb are used in known low alloyed high speed steels for forming metal carbides in the steel for obtaining a desired high toughness and abrasive resistance as well as a high strength and hardness of the steel. When adding such alloying elements one critical issue
is to ensure that the size of the metal carbides will be kept within a certain limit, since members of such steels will otherwise be very hard to machine, such as for manufacturing tools out of them, and also have poor mechanical properties.

The high speed steel most frequently occurring on the market today is the so-called M2, which may have compositions differing slightly, but mainly has the following composition in weight-%: C 0.90, Cr 4.2, Mo 5.0, W 6.4 and V 2.4. Cr is used for obtaining an appropriate hardening capacity of the steel, whereas the alloying elements Mo, W and V are used for together with the carbon forming metal carbides necessary for obtaining the hardness and wear and abrasive resistance aimed at.

There are of course continuously ongoing attempts to improve the mechanical properties of such high speed steels, but the present invention is not particularly directed thereto, but to solve another problem in common to known such high speed steels while at the same time keeping the mechanical resistance properties at a requested level. This problem relates to the costs for the alloying elements. These costs fluctuates over time and for that reason the selling price of high speed steels consists of a base price, which also contains some alloying element costs, as well as an alloying element extra surcharge. This means that at a peak of alloy element costs the alloy element extra surcharge can be a considerable part of the total selling price and sometimes even higher than the base price. This constitutes a great incitement for trying to partially or entirely substitute alloying elements, especially the most costly, in known high speed steels, such as in M2, by less costly ones without an apparent negative impact on the important properties of the steels.
SUMMARY OF THE INVENTION

The object of the present invention is to provide a high speed steel having mechanical properties being at least comparable to those of the known high speed steel M2 but with at least a partial substitution of one or more alloying elements thereof by other alloying elements making it possible to lower the costs of the steel would these substitute alloying elements be available to a lower cost than the former ones.

This object is according to the invention obtained by providing a high speed steel, which is characterized in that it contains in weight-%: C 0.8-1.2 %, N 0-0.2 %, Cr 2-6 %, Mo 3-5 %, W 0-1.2 %, V 0-3 %, Nb 0-2 %, Si 0.7-1.7 %, balance Fe and normal occurring impurities, wherein Mo + Si ≤ 6 in weight-%.

Thus, this steel may be considered to be low alloyed and a high speed steel with this composition has turned out to have mechanical properties being comparable to those of M2 discussed above, but which may result in a considerably reduced alloying element extra surcharge with respect thereto. This is due to the fact that Mo has been partially replaced by Si, which is possible without lowering the hardness and abrasive resistance of the steel. The content of W is also dramatically reduced with respect to that in M2. It has turned out that such a low content of W, i.e. 0-1.2 weight-%, is necessary for efficiently replacing Mo by Si while maintaining high hardness. Moreover, it has turned out that the content of Si should be at least 0.7 weight-% for resulting in a contribution to the hardness aimed at thereby. However, the content of Si should not be above 1.7 weight-%, since the hardness after soft annealing will then be too high and a member, such as a tool blank, of the steel will then be too difficult to machine. Mo + Si should be ≤ 6 in weight-%, since the metal carbide size in the steel will otherwise be too large.
According to an embodiment of the invention the content of Si is 0.7-1.6 weight-%.

According to another embodiment of the invention the content of Si is 1.0-1.7 weight-%, preferably 1.0-1.6 weight-%, more preferred 1.2-1.6 weight-% and most preferred 1.4-1.6 weight-%. It has turned out that Mo may be replaced by Si while maintaining the mechanical properties aimed at up to at least 1.6 weight-%, so that it is very preferred to have a content of Si close to this figure for fully benefit from the lower cost of Si compared to Mo.

According to another embodiment of the invention Mo + Si = 4.0-6.0 weight-%, especially 5.0-6.0 weight-%. This results in a sufficient hardness and abrasive resistance of the high speed steel according to the invention.

According to another embodiment of the invention the high speed steel comprises Mo and W in a relationship in weight-% of (Mo/W) > 3, preferably > 6, more preferred > 8, and most preferred >10. It has been found that this relationship of Mo/W should be above 3, preferably above 6 for making it possible for Si to contribute to the hardness of the steel, and it should more preferred be > 8 and even more preferred > 10. Said relationship may especially be 8-20 or 10-20.

According to another embodiment of the invention the content of Nb + V = 1.0-4.0 weight-%, preferably 2.0-3.0 weight-%. It has been found that V may be at least partially replaced by Nb while obtaining corresponding metal carbide properties, which would be favourable if the cost of Nb is lower.

According to another embodiment of the invention the high speed steel contains in weight-%: Cr 3.5-4.5 %, Mo 3.0-4.0 %, W 0.1-1.2 %, V 0.8-1.2 %, Nb 0.8-1.2 % and Si 1.3-1.6 %. A high speed steel with this composition, especially containing in weight-%: Cr approximately 4 %, Mo approximately 3.5 %, W
approximately 0.2 %, V approximately 1.0 %, Nb approximately 1.0 % and Si approximately 1.5 %, has turned out to have a hardness and wear and abrasive resistance as well as hardness after soft annealing being comparable to M2 while enabling a considerably lower alloying element extra surcharge of the selling price of this high speed steel with respect to M2.

According to another embodiment of the invention the high speed steel contains in weight-%: Cr 3.5-4.5 %, Mo 3.0-4.0 %, W 0.1-1.2 %, V 1.7-2.3 %, Nb max 0.2 % and Si 1.3-1.6 %. This embodiment corresponds to the embodiment mentioned above except for substantially entirely replacing Nb by V, which has turned out to be possible without changing the properties of the high speed steel and may be interesting when the selling price of Nb is higher then that of V.

The invention also relates to a use of a low alloyed high speed steel according to the invention for manufacturing a tool for hot working or chip cutting, machining or cold working, or an advanced machine element, such as a saw blade, a drill and a milling cutter as well as a tool for hot working of chip cutting, machining or cold working, or an advanced machine element, which comprises a high speed steel according to the present invention. The advantages of such a use and such a tool appear clearly from the discussion above.

The invention also relates to a process for producing a tool blank to be used for manufacturing a tool according to the invention, in which the process comprising the steps:

a) preparing a cast alloy member of a steel according to the present invention,
b) forging or hot pressing said cast alloy member to a predetermined shape,
c) hardening said member.
This process makes it possible to produce a suitable tool blank to be used for manufacturing a tool according to the invention, and preferred embodiments of such a process according to the invention are defined in the dependent appended process claims.

Further advantages as well as advantageous features of the invention will appear from the following description of embodiments thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig 1 is a graph showing the relationship between content of Si and Mo of different samples used in experiments carried out for high speed steels according to the present invention,

Fig 2 is a graph showing the relationship of Si-content and Nb/V-ratio of said samples subjected to said experiments,

Fig 3 is a graph of the soft annealed hardness versus Si-content for different samples subjected to said experiments,

Fig 4 and Fig 5 are graphs of hardness after hardening of said samples at 1180°C and at 1100°C, respectively,

Fig 6 and Fig 7 are graphs of the MC-carbide size and the total-carbide size, respectively, versus the content of Mo + Si of said samples according to said experiments, and

Fig 8 and
Fig 9 are graphs corresponding to those of Fig 6 and Fig 7, respectively, but for the Nb/V-ratio instead of the Mo + Si-content.

5 DETAILED DESCRIPTION OF THE INVENTION

A low alloyed high speed steel having excellent properties of hardness, wear and abrasive resistance and ability to be machined after soft annealing and producable at a highly competitive cost is obtained by a high speed steel according to the present invention. The high speed steel according to the invention contains in weight-%:

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight-%</th>
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<tbody>
<tr>
<td>C</td>
<td>0.8-1.2 %</td>
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<tr>
<td>N</td>
<td>0-0.2 %</td>
</tr>
<tr>
<td>Cr</td>
<td>2-6 %</td>
</tr>
<tr>
<td>Mo</td>
<td>3-5 %</td>
</tr>
<tr>
<td>W</td>
<td>0-1.2 %</td>
</tr>
<tr>
<td>V</td>
<td>0-3 %</td>
</tr>
<tr>
<td>Nb</td>
<td>0-2 %</td>
</tr>
<tr>
<td>Si</td>
<td>0.7-1.7 %</td>
</tr>
<tr>
<td>balance Fe and normal occurring impurities, wherein Mo + Si ≤ 6 in weight-%.</td>
<td></td>
</tr>
</tbody>
</table>

Carbon (C) should exist at a content of 0.8-1.2 weight-% for resulting in about 3 atom-% in the austenite at a typical hardening temperature, such as 1180°C, which is favourable for giving the material a hardness in the hardened and tempered condition that is suitable for its purposes. Carbon contributes to the formation of and adequate amount of primarily precipitated MC-carbides, which may be of the type M₆C and MC as disclosed further below. These carbides are important for obtaining a desired hardness and wear and abrasive resistance.

Nitrogen (N) may partially replace carbon and has the same function as the carbon while forming M-nitrides and carbon-nitrides. It should not be present in a content above 0.2 weight-
%, since this may result in production of large nitrides already in the melt.

Chromium (Cr) should exist in the steel at a content of at least 2 weight-% in order to, when dissolved in the matrix of the steel, contribute to the steel achieving adequate hardness and toughness after hardening and tempering. Chromium can also contribute to the resistance to wear of the steel by being included in primarily precipitated hard phase particles, mainly $M_6C$-carbides. Chromium shall not be present in a content above 6 weight-%, since that would only result in extra alloying element costs without adding anything to the hardness of the steel.

Molybdenum (Mo) is used for forming $M_6C$-carbide contributing to hardness and the resistance of wear of the steel. The content should be at least 3 weight-% for obtaining sufficient contribution to wear resistance and hardness of the steel, but it should not be above 5 weight-%, since the content of Mo + Si above 6 weight-% would result in a formation of too large MC-carbides resulting primarily in poorer mechanical properties and lower grindability and also in difficulties to machine the steel after soft annealing.

Tungsten (W) is used to form $M_6C$-carbides contributing to the resistance to wear of the steel. However, tungsten shall not be present in a content above 1.2 weight-%, since the relationship of the content of Mo/W shall be high, such as at least above 3 for enabling Si to contribute to the hardness of the steel and partially replacing Mo. Even if it is desired to have this relationship at a value above 6 it has turned out that a lower value, down to 3, will have no noticeable negative influence on the hardness of the steel. This understanding is favourable from the cost point of view, since it enables an extended use of less costly steel scrap often containing 0.4-1.2 weight-% W for producing the high speed steel according to the invention.
Vanadium (V) is used for forming MC-carbides contributing to resistance to wear and hardness of the material. MC-carbides are harder than M₆C-carbide, so that it is better to have MC-carbides of a certain size than M₆C-carbides of that size. However, the content of V may not be above 3 weight-%, since that would result in formation of large carbides reducing the easiness to machine the material after soft annealing, the grindability and the toughness of the material. Too high amounts of V also involve a risk of formation of MC-carbides already in the cast making the manufacturing process more difficult.

Niobium (Nb) may partially replace vanadium and has substantially the same behaviour as vanadium with respect to formation of MC-carbides and the properties thereof. The content of Nb should not be above 2 weight-%, since that may result in formation of too large MC-carbides. Due to the fact that Nb may replace V partially or entirely the one of these elements available to the lowest cost at the moment may be chosen.

Silicon (Si) should be present at a content of at least 0.7 weight-% for contributing to the hardness and abrasive resistance of the steel. However, higher contents are desired for the ability of Si to replace Mo, so that the content of the more costly Mo may be lowered and by that costs may be saved. The content of Si should not exceed 1.7 weight-%, and preferably not 1.6 weight-%, since the hardness after soft annealing will then be too high for making it comfortable to machine the material. Another effect of Si is that it destabilizes M₂C, which may be present in the cast, in favour of M₆C-carbides for transforming the M₂C into M₆C and MC when the cast is heat treated.

DESCRIPTION OF PREFERRED EMBODIMENTS

Table I below shows the composition of high speed steels according to the invention as well as reference steels in the form of M2 which were manufactured and subjected to experiments.
Small casts (0.5 kg) of alloy compositions were produced, in which the content of Si, Mo, Nb and V was varied in a systematic way in order to investigate the influence from partial replacement of Mo by Si and Nb by V. The other elements were fixed. C was added so that the carbon content in the austenite at hardening of 1180°C should be about 3 atom-%, which is a common level for many high speed steels. The carbon content in the austenite at 1180°C was calculated with the Thermo Calc software.

Table I: Chemical composition of the different grades. All in wt. % apart from N in ppm

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<tr>
<th>Sample</th>
<th>C in Aus</th>
<th>C</th>
<th>Si</th>
<th>Cr</th>
<th>Mo</th>
<th>W</th>
<th>V</th>
<th>Nb</th>
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</table>

The samples were produced in different series 3-x, 4-x and 5-x while varying the content of Si versus the content of Mo as shown in Fig 1 and the content of Si versus the ratio of Nb/V as shown in Fig 2. The filled dots 3 relate to the alloys in series 3-x, the open markers 4 in series 4-x and the rings 5 with a cross to the series 5-x. Markers with a line connecting to a dot or ring are for pressed samples.

Most of the casts were produced through a standard practice involving a step of heating up to 1550°C under argon atmosphere and holding at melting temperature 25 minutes at 1550°C with argon stirring in the melt and 5 minutes at 1550°C without stirring in melt to decrease porosity, followed by a cooling down to 25°C with furnace shut down under argon atmosphere. The cooling down speed was controlled to correspond to that of a commercial cast. The last three samples in Table I were pro-
duced according to a somewhat modified so called best practice.

The different sample casts of Table I were then forged, but some of them not possible to forge were instead hot pressed. "Press" used in Table II indicates that the cast sample in question was hot pressed.

After forging or pressing the material was soft annealed at 880°C and the soft annealed hardness was measured. Thereafter samples were hardened at both 1180°C and at 1100°C, followed by a 2 x 560°C 1 hour tempering. Hardness was measured by HRC. If possible, grindability (G-ratio) was measured on the forged material. Total and MC-carbide size was measured on hardened samples. The MC-carbide size was measured in ten different fields of view in 1000x magnification and the three largest MC-carbides were determined for each such field of view and the average of the 30 measurement values thus obtained was determined as the measured MC-carbide size. The total-carbide size was determined in the same way, but also M₆C-carbides were then considered, so that the three largest of any type of metal carbides present in each said field of view were determined. The results of these experiments and measurements are shown in Table II below.

Table II: Dimension after forging, soft annealed hardness, heat treated hardness, carbide size and grindability (G-ratio) of material from different casts.

<table>
<thead>
<tr>
<th></th>
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<td>3-1</td>
<td>15</td>
<td>243</td>
<td>64,1</td>
<td>66,4</td>
<td>14,8</td>
<td>13,8</td>
<td></td>
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<td>3-2</td>
<td>14</td>
<td>243</td>
<td>63,8</td>
<td>65,7</td>
<td>16,1</td>
<td>14,0</td>
<td>1,8</td>
</tr>
<tr>
<td>3-3</td>
<td>17</td>
<td>236</td>
<td>62,9</td>
<td>65,3</td>
<td>17,1</td>
<td>15,2</td>
<td></td>
</tr>
<tr>
<td>3-3 Bis</td>
<td>11</td>
<td>229</td>
<td>62,2</td>
<td>64,4</td>
<td>15,8</td>
<td>15,5</td>
<td>1,8</td>
</tr>
<tr>
<td>3-4</td>
<td>13</td>
<td>239</td>
<td>63,8</td>
<td>65,7</td>
<td>14,5</td>
<td>13,3</td>
<td>2,5</td>
</tr>
<tr>
<td>3-5</td>
<td>14</td>
<td>258</td>
<td>64,2</td>
<td>66,1</td>
<td>16,6</td>
<td>17,2</td>
<td>2,1</td>
</tr>
<tr>
<td>4-1</td>
<td>Press</td>
<td>237</td>
<td>62,5</td>
<td>65,3</td>
<td>30,9</td>
<td>12,2</td>
<td></td>
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<tr>
<td>4-2</td>
<td>20</td>
<td>251</td>
<td>65,0</td>
<td>66,9</td>
<td>13,7</td>
<td>11,2</td>
<td></td>
</tr>
<tr>
<td>4-3</td>
<td>14</td>
<td>274</td>
<td>64,5</td>
<td>65,9</td>
<td>13,5</td>
<td>11,2</td>
<td>2,3</td>
</tr>
</tbody>
</table>
Fig 3 shows a soft annealed hardness $S_A$ versus the Si-content in weight-% in accordance with Table II. The different markers have the same meaning as in Fig 1 and 2, and 0 B stands for series B-x, whereas a line is added to the markers for materials being hot pressed. The values for M2 are shown to the left. There seems to be no apparent negative influence from Si-content upon the soft annealed hardness up to about 1.2 weight-% Si. The soft annealed hardness is increased by about 30 HB between about 1.5 and 2 weight-%, whereas for even higher Si-content there is an even larger increase in soft annealed hardness. Thus, there is no apparent negative effect on soft annealed hardness for Si-content up to approximately 1.3 weight-% and only a slightly negative effect up to about 1.7 weight-%. Previous studies have shown a clear relationship between soft annealed hardness and easiness to machine after soft annealing, so that the former shall be kept at a low level for improving the latter.

It appears from Fig 4 and Fig 5 that the hardness (HRC, 1180) and hardness (HRC, 1100), respectively, will increase when increasing the Si-content up to 0.7 weight-%, but no major influence on the hardness is seen when varying the Si-content between 0.7 and 2.0 weight-%. From Fig 5 it is interesting to notice that at a hardening temperature of 1100 $^\circ$C the experimental
high Si grades are in average almost 4 HRC higher in hardness than the M2 samples, whereas at 1180°C the difference is not more than 1 HRC at maximum. Thus, the benefit on hardness from a high Si-content seems to be more pronounced at lower hardening temperatures. This is an advantage, since the energy consumption will be lower and the stress on the furnace equipment will be lower when using lower hardening temperatures.

The MC- and total carbide size of the different samples according to Table II versus Mo + Si-content are shown in Fig 6 and Fig 7, whereas the MC- and total carbide size versus the Nb/V-ratio are shown in Fig 8 and Fig 9. Linear regression analysis was used in order to estimate the influence from different parameters such as Si-content, Nb-content, Mo + Si-content etc. In this analysis a linear dependence between a parameter and the carbide size was assumed, which of course is not necessarily true. The regression analysis indicate that the only statistically reliable influence on MC-carbide size and total carbide size is from the total Mo + Si-content, in which case an increased Mo + Si-content implies a larger MC-carbide size. Apart from Mo + Si-content, Nb/V-ratio seems to have some influence on MC-carbide size. For the comparable low Nb + V contents in these studies, the trend seems to be a decreasing MC-carbide size when increasing Nb/V-ratio. Furthermore, the accuracy when determining the MC-carbide size experimentally is about ± 1 μm.

Furthermore, the grindability was measured from G-ratio, and the higher this ratio the easier it is to remove material from the steel by grinding. For these samples no relation between MC-carbide size and G-ratio could be observed.
CONCLUSION

It is possible to produce a low alloyed high speed steel with partial replacement of Mo and W by Si and partial replacement of V by Nb. However, the Si-content should preferably not be higher than 1.7 weight-%, since above that level the soft annealed hardness will increase and in addition there are no apparent extra benefits on the hardened hardness. No apparent negative influence could be detected by a partial replacement of V by Nb as long as the total content of Nb does not exceed 2 weight-%. This study indicates that a tentative material with about 4 Cr, 1.5 Si, 3.5 Mo, 0.2 W, 1 V and 1 Nb (all in weight-%) will compare to M2 have comparable soft annealed hardness, comparable hardness, comparable or somewhat lower grindability, and judging from the structure and carbide size, the material will compared to M2 have comparable or somewhat lower wear resistance and comparable strength and impact toughness. It would especially be more low alloyed and should result in lower costs for alloying elements.

It is pointed out that the high speed steel according to the invention may also be allowed to contain smaller amounts of Mn (such as up to 0.4 weight-%) and Co (such as up to 1.0 weight-%).
Claims

1. High speed steel, characterized in that it contains in weight-%:
   
   C  0.8-1.2 %
   N  0-0.2 %
   Cr 2-6 %
   Mo 3-5 %
   W 0-1.2 %

   balance Fe and normal occurring impurities, wherein Mo + Si ≤ 6 in weight-%.

2. High speed steel according to claim 1, characterized in that the content of Si is 0.7-1.6 weight-%.

3. High speed steel according to claim 1, characterized in that the content of Si is 1.0-1.7 weight-%, preferably 1.0-1.6 weight-%, more preferred 1.2-1.6 weight-% and most preferred 1.4-1.6 weight-%.

4. High speed steel according to any of the preceding claims, characterized in that the content of Mo + Si = 4.5-6.0 weight-%.

5. High speed steel according to claim 4, characterized in that the content of Mo + Si = 5.0-6.0 weight-%.

6. High speed steel according to any of the preceding claims, characterized in that it comprises Mo and W in a relationship in weight-% of (Mo/W) > 3, preferably > 6, more preferred > 8 and most preferred >10.
7. High speed steel according to claim 6, characterized in that said relationship is 8-20 or 10-20.

8. High speed steel according to any of the preceding claims, characterized in that the content of Nb + V = 1.0-4.0 weight-%, preferably 2.0-3.0 weight-%.

9. High speed steel according to any of the preceding claims, characterized in that it contains in weight-%:

<table>
<thead>
<tr>
<th>Element</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr</td>
<td>3.5-4.5 %</td>
</tr>
<tr>
<td>Mo</td>
<td>3.0-4.0 %</td>
</tr>
<tr>
<td>W</td>
<td>0.1-1.2 %</td>
</tr>
<tr>
<td>V</td>
<td>0.8-1.2 %</td>
</tr>
<tr>
<td>Nb</td>
<td>0.8-1.2 %</td>
</tr>
<tr>
<td>Si</td>
<td>1.3-1.6 %</td>
</tr>
</tbody>
</table>

10. High speed steel according to claim 9, characterized in that it contains in weight-%:

<table>
<thead>
<tr>
<th>Element</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr</td>
<td>approximately 4 %</td>
</tr>
<tr>
<td>Mo</td>
<td>approximately 3.5 %</td>
</tr>
<tr>
<td>W</td>
<td>approximately 0.2 %</td>
</tr>
<tr>
<td>V</td>
<td>approximately 1.0 %</td>
</tr>
<tr>
<td>Nb</td>
<td>approximately 1.0 %</td>
</tr>
<tr>
<td>Si</td>
<td>approximately 1.5 %</td>
</tr>
</tbody>
</table>

11. High speed steel according to any of the preceding claims, characterized in that it contains in weight-%:

<table>
<thead>
<tr>
<th>Element</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cr</td>
<td>3.5-4.5 %</td>
</tr>
<tr>
<td>Mo</td>
<td>3.0-4.0 %</td>
</tr>
<tr>
<td>W</td>
<td>0.1-1.2 %</td>
</tr>
<tr>
<td>V</td>
<td>1.7-2.3 %</td>
</tr>
<tr>
<td>Nb</td>
<td>max 0.2 %</td>
</tr>
<tr>
<td>Si</td>
<td>1.3-1.6 %</td>
</tr>
</tbody>
</table>

12. Use of a high speed steel according to any of claims 1-11 for manufacturing a tool for hot working or chip cutting, machin-
ing or cold working, or an advanced machine element, such as a saw blade, a drill and a milling cutter.

13. A tool for hot working or chip cutting, machining or cold working, or an advanced machine element, characterized in that it comprises a high speed steel according to any of claims 1-11.

14. A process for producing a tool blank to be used for manufacturing a tool according to claim 13, said process comprising the steps:
   a) preparing a cast alloy member of a steel according to any of claims 1-11,
   b) forging or hot pressing said cast alloy member to a predetermined shape,
   c) hardening said member.

15. A process according to claim 14, characterized in that it comprises a further step d) of soft annealing said member, and that step d) is carried out after step b) and before step c).

16. A process according to claim 14 or 15, characterized in that it comprises a further step e) of tempering said member, and that said step e) is carried out after step c).

17. A process according to any of claims 14-16, characterized in that said hardening is carried out at a temperature of about 1200°C, such as at about 1180°C, or at about 1100°C.

18. A process according to claim 15, characterized in that said soft annealing is carried out at a temperature of 850°C-900°C, such as at about 880°C.

19. A process according to claim 16, characterized in that said tempering is carried out at a temperature of 500°C-600°C,
especially at about 560°C, for a period of time of 0.5-2 hours, optionally repeated one time or more.
INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2008/051034

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: C22C, C21D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>US 5651842 A (NAKAMURA, HIDEKI ET AL), 29 July 1997 (29.07.1997), column 9, line 45 - line 53; column 7, line 23 - line 28, claim 1, abstract, table 1</td>
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</table>

Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search: 16 March 2009

Date of mailing of the international search report: 18-03-2009

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Authorized officer
Kristina Norden/Eδ
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Form PCT/ISA/210 (second sheet) (July 2008)
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<td>US 3211593 A (KREKELER, KARL AUGUST), 12 October 1965 (12.10.1965), the whole document</td>
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International patent classification (IPC)
C22C 38/34 (2006.01)
C21D 1/18 (2006.01)
C22C 38/22 (2006.01)
C22C 38/24 (2006.01)
C22C 38/26 (2006.01)

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Cited literature, if any, will be enclosed in paper form.
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<td>EP</td>
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<td>12/10/1965</td>
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