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## SINTERED HARD METAL ALLOY

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The present invention relates to a sintered hard metal alloy having a high wear resistance and great tenacity and being adapted for cutting (machining) material, e.g., steel, which give long chips, which sintered hard metal alloy is of the type consisting substantially of tungsten carbide, titanium carbide, tantalum and/or niobium carbide and an auxiliary or bonding metal or alloy selected preferably from the iron group of the periodic table, for instance cobalt, nickel and/or iron.

This type of alloy has a structure built up of the following phases: a  $\alpha$ -phase consisting of WC, a  $\gamma$ -phase consisting of a solid solution of WC and TaC/NbC in TiC, and the  $\beta$ -phase consisting of auxiliary or bonding metal, usually cobalt. In general, these phases expressed in volume percent, total 100 volume percent. However, in certain cases also other phases may be present in very small insignificant amounts. The sum of the volume percentages of the alpha, beta and gamma phases should exceed at least 95, and preferably should amount to 97–99, volume percent.

It has now been found (and this discovery forms the basis of the present invention) that if the composition and structure of such an alloy is chosen within special relatively narrow ranges the alloy exhibits a surprising increase in wear resistance and toughness. Alloys according to the present invention have been found to be particularly suitable for machine tools for cutting materials like steel giving long chips, but are not limited to this particular application. If an alloy according to the invention is used as a cutting tool for turning operations, the same permits higher cutting speeds and/or greater rate of feed and cutting depth. Likewise an alloy according to the invention is suitable for machining of steel under unfavorable conditions, as in relatively unstable machines, or machining with interrupted cuts, in which operation a better life for the hard metal insert is obtained than has been realized heretofore: very good results in comparison with previously known alloys have also been obtained in the milling of steel.

According to this invention a sintered hard metal alloy comprises in addition to WC, substantially 18–21% by weight TiC, 14–18% by weight TaC and/or NbC and 8.5–11% by weight of auxiliary or bonding metal such as Co, Ni and/or Fe, the amount of the  $\beta$ -phase of the alloy and the amount of the  $\gamma$ -phase being related to one another by the relationship  $100-1.2\beta > \gamma > 100-2.5\beta$ , wherein  $\beta$  and  $\gamma$  represent the amounts of the respective phases expressed in volume percent.

It should here be mentioned that where in this specification and the accompanying claims we use the expression "TaC/NbC" the same is intended to convey that the alloy contains either or both the compounds TaC and NbC, and that where a percentage figure is given against the expression "TaC/NbC" this refers to the content of (TaC+NbC) in the alloy.

The alloy may have a structure in which the amount of  $\gamma$ -phase exceeds  $100-2\beta$  and at the same time is lower than  $100-1.2\beta$ ; and in many cases the amount of  $\gamma$ -phase

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is lower than  $100-1.5\beta$ . The quantity of the  $\beta$ -phase depends on the content of the auxiliary metal and is normally within the range 10.5–15% and may expediently be within the narrower range 11–14%. The amounts of the various phases  $\alpha$ ,  $\beta$  and  $\gamma$  are always represented as volume percentages throughout the specification.

In comparison with the other known hard metal alloys of this kind, the alloy of this invention has an increased amount of  $\gamma$ - and  $\beta$ -phase. This has been shown to be of great importance for obtaining a high quality alloy with increased wear-resistance and at the same time increased toughness.

In some of the previously known hard metal alloys which have been used the amount of the  $\gamma$ -phase has been lower than 100–3 $\beta$  and similarly the TiC, TaC and Co contents have been considerably lower than the characteristic limits required for the alloy of this invention. In comparison with these known alloys, the alloy of the present invention shows an improvement both in resistance to wear and in toughness. For instance, practical tests have shown that by turning in a lathe with a hard metal alloy in accordance with this invention there has been obtained an increase in the number of machined details of up to 160% between the re-grindings.

The increase in content of the  $\gamma$ -phase may be obtained in various manners. Thus, the carbide powder to be sintered may consist substantially of carbides in solid solution with each other, the so-called double carbides (Ti, W)C, and/or triple carbides (Ti, Ta, W)C. It is also possible to regulate the content of the  $\gamma$ -phase by adjusting the sintering temperature and/or sintering time. For example, with a rise in the sintering temperature and/or extension of the sintering time a greater quantity of the free tungsten carbide, i.e., the  $\alpha$ -phase, may be dissolved in the  $\gamma$ -phase and is, with a suitable rate of cooling, kept in the  $\gamma$ -lattice.

The increase in content of the  $\beta$ -phase, i.e., the auxiliary metal content, is made possible by means of the relatively high content of TaC/NbC, which prevents the plastic deformation which (in connection with high contents of auxiliary metal) otherwise appears; such plastic deformation being particularly noticeable in the machining of steel with high cutting speeds and feeds.

For obtaining these unusual properties for the hard metal alloy according to this invention the stoichiometrical composition of the alloy is of great importance, the limits of which have been indicated above. However, it is generally advantageous if the content of titanium carbide and TaC/NbC of the hard metal alloy is within the limits 18–23% by weight TiC and 14–18% by weight TaC/NbC, respectively. The amount of the auxiliary metal, which advantageously consists of cobalt or is mainly cobalt, is preferably chosen within the range 8.5–11% by weight and often within the range 9–11% by weight.

Especially good properties have been obtained for hard metal alloys containing 18–21% by weight TiC, 14–18% by weight TaC/NbC and 9–10% by weight Co.

The invention will now be described in greater particularity with reference to the following illustrative but non-limitative specific examples:

### Example 1

Composition by weight:

19% TiC  
12.8% TaC  
3.2% NbC  
9.5% Co  
Remainder WC

The above components, in the relative amounts stated, were ground together to such a grain size that the ensuing

sintered hard metal alloy product had a grain size of 2-3 $\mu$ . The finely ground mixture was, after being compressed, sintered in a vacuum oven at about 1500° C. for about one hour.

This alloy consisted of 6.9 volume-percent of  $\alpha$ -phase, 82 volume-percent of  $\gamma$ -phase and 11.1 volume-percent of  $\beta$ -phase.

With this alloy tests were carried out with coarse turning of 10.5 cm. shells and on the average 142 shells per re-grinding were machined as compared with 50 shells with the previously known best grade, i.e., a grade of convention type consisting of 15% TiC, 7% Co and the remainder WC.

#### Example 2

Milling tests were carried out with the alloy, according to the invention described in Example 1, with the following results:

Material: Hardened and tempered steel containing (by weight) C=0.40%, Si=0.30%, Mn=0.60%, Cr=0.8% and Ni=1.2%.  $H_B$  about 220 (Brinell hardness).

Tools: Milling cutter with six sets of cutting inserts to give six cuts, every other set being of hard metal in accordance with the invention (sintered hard metal according to the analyses and data in Example 1), in the following table designated "A," and the other alternate sets being of hard metal of the conventional type containing 15% (by weight) TiC, 7% (by weight) Co and the remainder WC, and in the following table designated "B." Average wearland is the wear on the clearance side of the hard metal tool bit.

| Cutting data           |                          |                      | Effective milling time in minutes | Average wearland in mm. |      | Number of chipped cutting edges |   |
|------------------------|--------------------------|----------------------|-----------------------------------|-------------------------|------|---------------------------------|---|
| cutting speed, m./min. | Feed, mm./cutting insert | Cutting depth in mm. |                                   | B                       | A    | B                               | A |
| 60                     | 0.21                     | 2.5                  | 1                                 |                         |      | 3                               | 0 |
| 74.5                   | 0.21                     | 2.5                  | 99                                | 0.20                    | 0.15 | 2                               | 0 |
| 94                     | 0.21                     | 2.5                  | 63                                | 0.25                    | 0.15 | 2                               | 0 |
| 120                    | 0.166                    | 2.5                  | 63                                | 0.23                    | 0.22 | 0                               | 0 |
| 150                    | 0.166                    | 2.5                  | 32                                | 0.30                    | 0.17 | 0                               | 0 |

Grade "A," according to the invention, with the milling tests which were carried out, showed itself to be superior to "B" in many respects. This was true both as to toughness and resistance to wear. The amount of cutter wear was remarkably low and even for "A," and concerning toughness in contrast to the relatively coarse chipping appearing on "B" "A" was completely undamaged.

#### Example 3

Tests were performed in a thread machine as stated below:

Machine: Thread machine (Cri-Dan make). Type B, 1954.

Machine detail: Spindle.

Material: Hardened and tempered chrome-nickel steel, containing (by weight) C=0.3%, Si=0.3%, M=0.8%, Cr=0.8% and Ni=1.3%.  $H_B$  about 285 (Brinell hardness).

Operation: Thread cutting M 16 x 1.5, length 20 mm.

Number of cuts: 14.

Cutting speed: 90 m./min.

Hard metal grades: "A" was the hard metal alloy according to the invention mentioned in Example 1, "B" was the previously known best grade for the above-mentioned operation, containing 22% (by weight) TiC, 9% (by weight) Co, and the remainder WC, and "C" was a hard metal alloy, containing 19% (by weight) TiC, 3% (by weight) TaC, 8.5% (by weight) Co, and the remainder WC.

Two tests were made with grade "A." In these tests

315 and 272 pieces of details respectively were threaded before the cutting insert had to be re-ground.

With grade "B," on an average, about 100 details were threaded per re-grinding.

Grade "C" gave the result 42 and 52 details respectively threaded per re-grinding.

#### Example 4

An alloy having the following composition by weight:

19% TiC  
7.2% TaC  
1.8% NbC  
9% Co

The remainder WC, and containing in volume percent 11.5%  $\alpha$ -phase, 78%  $\gamma$ -phase and 10.5%  $\beta$ -phase was prepared in the manner described in Example 1 above. This alloy was tested by turning of spindle sleeves in a Fischer lathe against a hard metal alloy grade containing 18.5% (by weight) TiC, 2% (by weight) TaC, 1% (by weight) NbC, 9% (by weight) Co and the remainder WC. The cutting speed was 130 m./min., the feed 0.36 mm./revolution and the cutting depth 3-11 mm. The tools in both cases consisted of steel holders with clamped hard metal alloy inserts. The grade according to the invention gave about an 80% better result than the other grade.

#### Example 5

Composition by weight:

25% TiC  
12% TaC  
11% Co  
Remainder WC

The alloy contained in volume 3%  $\alpha$ -phase, 85%  $\gamma$ -phase and 12%  $\beta$ -phase. This alloy was tested in the most widely differing machining operations and also with different steel grades and proved to possess a very high toughness in combination with a very good resistance to wear.

#### Example 6

Still another alloy according to the invention which has given very good results contained approximately (by weight):

19% TiC  
6% TaC  
6% NbC  
9.5% Co  
Remainder WC

In the manufacture of alloys according to the invention it has proved advantageous to include titanium carbide in the form of the so-called double carbide (Ti, W)C, containing for example 50% titanium carbide and 50% tungsten carbide. Tantalum and/or niobium carbide may either be added in the form of simple carbides or in the form of a solid solution (Ta, Nb)C. Of course it is also possible to include carbides in other solid solutions, for example in the form of (Ti, Ta, W)C. The above-mentioned amounts of the components are ground together with tungsten carbide and cobalt to a grain size, which will give the sintered hard metal alloy product a grain size of preferably 2-3 $\mu$ . Pressed components of this powder are suitably sintered in a vacuum oven at about 1500° C. for about 1 hour.

We claim:

1. A sintered hard metal alloy especially for machining steel consisting essentially of the following components in the following percentages by weight: TiC 18-21%; a carbide of the group consisting of TaC and NbC and mixtures of TaC and NbC, 14-18%, the content of said carbide being less than the content of TiC; auxiliary bonding metal of the group consisting of Ni, Co and Fe, 8.5-11%; the remainder being substantially all WC, said alloy being further characterized in that

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said alloy is composed of a  $\gamma$ -phase consisting of a solid solution, in TiC, of all of the carbide of the group consisting of TaC and NbC and mixtures of TaC and NbC and substantially all of the WC and an  $\alpha$ -phase consisting of the remaining undissolved WC and a  $\beta$ -phase consisting of the auxiliary bonding metal, the amount of the  $\beta$ -phase thereof and the amount of the  $\gamma$ -phase thereof being related to one another by the relationship

$$100-1.2\beta > \gamma > 100-2.5\beta$$

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and the sum of the amounts of the three phases  $\alpha$ -,  $\beta$ - and  $\gamma$ -equalling 100, where  $\alpha$ -,  $\beta$  and  $\gamma$  represent the amounts of the respective phases in volumes percent.

2. Sintered hard metal alloy according to claim 1, 15

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wherein the bonding metal consists of Co, and the content by weight thereof is within the range 9-10%.

3. Sintered hard metal alloy according to claim 1, and having substantially the following composition by weight:

19% TiC  
12.8% TaC  
3.2% NbC  
9.5% Co  
Remainder WC

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