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(54) Calcium treated boron alloyed steel with improved machinability.

(57) The invention concerns a calcium-treated steel alloy, wherein the hardenability effect of boron is combined with an improved machinability. The chemical composition of the steel in percentages by weight is 0.01 - 0.5% carbon, 0.01 - 2.0% silicon, 0.4 - 1.6% manganese, 0.01 - 0.3% sulphur, 0 - 2.0% chromium, 0 - 0.8% molybdenum, 0.002 - 0.02% boron, 0 - 0.015% titanium, 0.005 - 0.014% aluminium, 0.0015 - 0.01% calcium and in addition B = (0.5 - 2) × (N - Ti/3.4), wherein B is the boron content, N the nitrogen content and Ti the titanium content in percentages by weight.

EP 0 265 402 A1

Description

Calcium treated boron alloyed steel with improved machinability

The object of the present invention is improved machinable calcium treated boron alloyed steel, wherein a free boron content sufficient for hardenability is obtained without Ti and/or Al contents disadvantageous to machinability. With this invention the weaknesses of the known techniques are avoided.

In the known heat treated boron alloyed steels the free boron content sufficient for hardenability is obtained by binding the dissolved nitrogen aluminium and/or titanium. The machinability of the known steels is poor for the following reasons:

- As a result of titanium alloying (about 0.02-0.05 wt-%) required to protect boron, the steel contains extremely hard large TiN particles which have a disadvantageous effect on machinability.
- The high Al content (0.05-0.1 wt-%) required to protect the boron impairs machinability.
- The machinability of boron steels of these known types cannot be essentially improved by calcium treatment.

A summary of the invention is presented in the following.

In the steel of the present invention amounts of Al and Ti added are so low that they do not bind all the dissolved nitrogen. The excessive part of nitrogen, which remains after the binding by titanium and aluminium, is bound to boron to give boron nitrides. A sufficient amount of boron is alloyed so that in addition to the boron in nitrides, the steel contains about 10-30 weight-ppm chemically free boron.

Titanium alloying is restricted to prevent the precipitation of large so-called primary titanium nitrides in the molten state. The maximum amount of titanium added depends on the nitrogen content of the steel. If desired, the titanium may be left out altogether. At least 0.005 wt-% of aluminium is alloyed in order to kill the steel, to reduce the grain size and to obtain the correct type of non metallic inclusions. Aluminium contents of over 0.014 wt-% are not alloyed due to the deterioration of machinability.

It is also characteristic for the steel of the present invention that it has been calcium treated in ladle. The calcium treatment improves the machinability of the steel. Full advantage is gained from the calcium treatment because high Ti or Al contents are not used.

It is furthermore characteristic for the steel of the present invention that it contains the following alloying elements shown below in percentages by weight:

carbon 0.01 - 0.50%
silicon 0.01 - 2.00%
manganese 0.40 - 1.60%
sulphur 0.01 - 0.30%
chromium 0 - 2.00%
molybdenum 0 - 0.80%

The use of the steel determines the alloying element combination selected.

In the following the technological background of the invention and the test results obtained with the steels relating to the invention will be described.

Boron is an element which intensifies the hardenability of steel considerably with very low contents of chemically free boron.

It is characteristic for the hardenability intensifyig effect of boron that maximum effect is obtained with a certain free boron content (0.001-0.004 wt-%) and that the obtained increase in hardenability diminishes as the carbon and alloying element contents increase.

Since boron has a hardenability intensifying effect only when it is dissolved in steel in chemically free form, it should be ensured that boron is not bound in compounds - mainly BN or B_2O_3 - or that the free boron content is the said 0.001-0.004 wt-% also after a part of the boron is bound in the above-mentioned compounds.

In the established steel making technique, the obtaining of a stable hardenability effect of boron is ensured by adding nitrogen binding elements such as Ti and/or Al (also Zr, V, Nb) and a standard amount of boron after a thorough deoxidation.

It is also possible to alloy so much boron that although a part of it is bound in BN, enough boron still remains to guarantee the hardenability effect. This requires, however, advanced steel making technique because insufficiently low boron alloying results in the loss of hardenability and excessively high alloying in a decrease in hardenability and furthermore makes the steel brittle.

The increase in hardenability achieved by boron alloying, that is, the boron hardenability effect (Bf) is usually defined as the ratio of the ideal critical diameter (DI) measured by the Jominy-test (SFS-standard 2375) to the ideal critical diameter (DIchem) calculated on the basis of the chemical analysis (excluding boron):

$$Bf = DI/DIchem$$

The chemical analyses of the test steels are given in Table 1 and the results of their hardenability tests are shown in Table 2. The test results clearly show that the boron hardenability effect is achieved on exceeding a certain value of the ratio B/(N - Ti/3.4), wherein B is the boron content, N the nitrogen content and Ti the titanium content in percentages by weight. The intensity of the effect increases rapidly at first as the free boron content increases, but reaches then its maximum value which is dependent on the carbon and alloying element contents. The boron hardenability effect is thus achieved without Al and/or Ti alloying with a sufficiently high boron content.

Table 2 The hardenability effect and B/(N - Ti/3.4) ratio values on test steels

Steel	Bf	B/(N - Ti/3.4)
1	1.74	1.14
2	1.13	0.72
3	1.61	0.89
4	1.67	0.99
5	1.80	1.50
6	1.89	1.18

The conventional boron-protecting methods, titanium and/or aluminium alloying, impair machinability. Titanium forms extremely hard cubic TiN particles which wear machining tools abrasively. This is shown by the shorter tool life when machining titanium alloyed steels. Fig. 1.

By means of calcium treatment the machinability of steel is improved by modifying non metallic inclusions. Oxides in untreated steels (aluminium oxides, silicates) are extremely hard and thus wear the machining tool abrasively. In calcium treated steels oxides are softer and in addition enveloped by a soft sulphide case. These modified non metallic inclusions cause less abrasive wear of machining tools. At high machining speeds the inclusions of calcium treated steel also form a protecting film on the surfaces of machining tools. Thus, the tool lives are substantially longer when machining calcium treated steels. Fig. 2.

The calcium treatment does not, however, affect the titanium nitride particles. Therefore, the machinability of titanium protected boron steel cannot be improved by calcium treatment. Fig. 3.

When aluminium is used to protect boron, the aluminium contents required are high which is known to impair the machinability of steel.

When the protection of boron is carried out according to the present application by means of excess boron alloying fixed to the nitrogen content of the steel, high titanium and/or aluminium contents are not required. The impairment of machinability caused by the above-mentioned alloying elements can thus be avoided,and an overall improvement of machinability is achieved by calcium treatment. Fig. 4.

Into the steel of the present invention it is also alloyed at least 0.01% sulphur because it is well known that sulphur addition improves machinability.

Table 1. Chemical analyses of the test steels relating to the invention and those of the comparison steels in percentages by weight, B and N in ppm

Steel	C	Si	Mn	P	S	Cr	Ni	Mo	Al	Ti	B	N	Ca	
1 Test steel	0.17	0.20	0.49	0.021	0.018	0.95	0.09	0.01	0.005	0.001	125	110	-	
2 "	0.16	0.19	0.43	0.020	0.022	0.95	0.14	0.02	0.006	0.001	72	100	-	
3 "	0.11	0.28	0.93	0.024	0.048	1.15	0.15	0.02	0.005	0.001	103	115	-	
4 Steel of the invention	0.27	0.25	1.20	0.025	0.030	0.42	0.16	0.03	0.007	0.002	99	100	48	1)
5 "	0.31	0.27	1.25	0.021	0.029	0.40	0.13	0.01	0.012	0.001	120	80	55	1)
6 "	0.28	0.23	1.14	0.024	0.027	0.47	0.17	0.02	0.005	0.010	83	100	35	1)
7 Comparison steel	0.41	0.18	0.69	0.025	0.023	1.10	0.21	0.17	0.006	-	-	-	-	
8 "	0.40	0.25	1.45	0.025	0.035	0.57	0.16	0.06	0.016	0.022	35	-	-	
9 "	0.40	0.27	1.19	0.024	0.040	0.25	0.15	0.06	0.011	-	-	-	56	1)
10 "	0.41	0.22	1.23	0.022	0.028	0.23	0.15	0.05	0.020	-	-	-	-	
11 "	0.41	0.28	1.33	0.019	0.041	0.52	0.25	0.03	0.031	0.030	28	-	-	
12 "	0.42	0.23	1.26	0.033	0.025	0.39	0.18	0.03	0.013	0.028	27	-	-	
13 "	0.28	0.23	1.23	0.020	0.032	0.35	0.25	0.04	0.012	0.033	39	-	55	1)

1) Calcium treated

Claims

1. Calcium treated hardenable boron alloyed steel, **characterized** in that the steel combines both an improved machinability and a hardenability intensifying effect of boron and the chemical composition of the steel in percentages by weight is:

carbon	0.01 - 0.5%
silicon	0.01 - 2.0%
manganese	0.4 - 1.6%
sulphur	0.01 - 0.3%
chromium	0 - 2.0%
molybdenum	0 - 0.8%
boron	0.002 - 0.02%
titanium	0 - 0.015%
aluminium	0.005 - 0.014%
calcium	0.0015 - 0.01%

and in addition

$B = (0.5 - 2) \times (N - Ti/3.4)$

wherein B is the boron content, N the nitrogen content and Ti the titanium content in percentages by weight.

2. Steel as claimed in claim 1, **characterized** in that the contents of boron and titanium in percentages by weight are:

boron	0.004 - 0.02%
titanium	0 - 0.005%.

3. Steel as claimed in claim 1, **characterized** in that the contents of boron and titanium in percentages by weight are:

boron	0.007 - 0.02%
titanium	0 - 0.005%.

4. Steel as claimed in claim 1, **characterized** in that the content of titanium in percentage by weight is 0.005 - 0.015%.

5. Steel as claimed in any one of the claims 1 - 4, **characterized** in that the content of sulphur in percentage by weight is 0.01 - 0.015%.

6. Steel as claimed in any one of the claims 1 - 4, **characterized** in that the content of sulphur in percentage by weight is 0.01 - 0.05%.

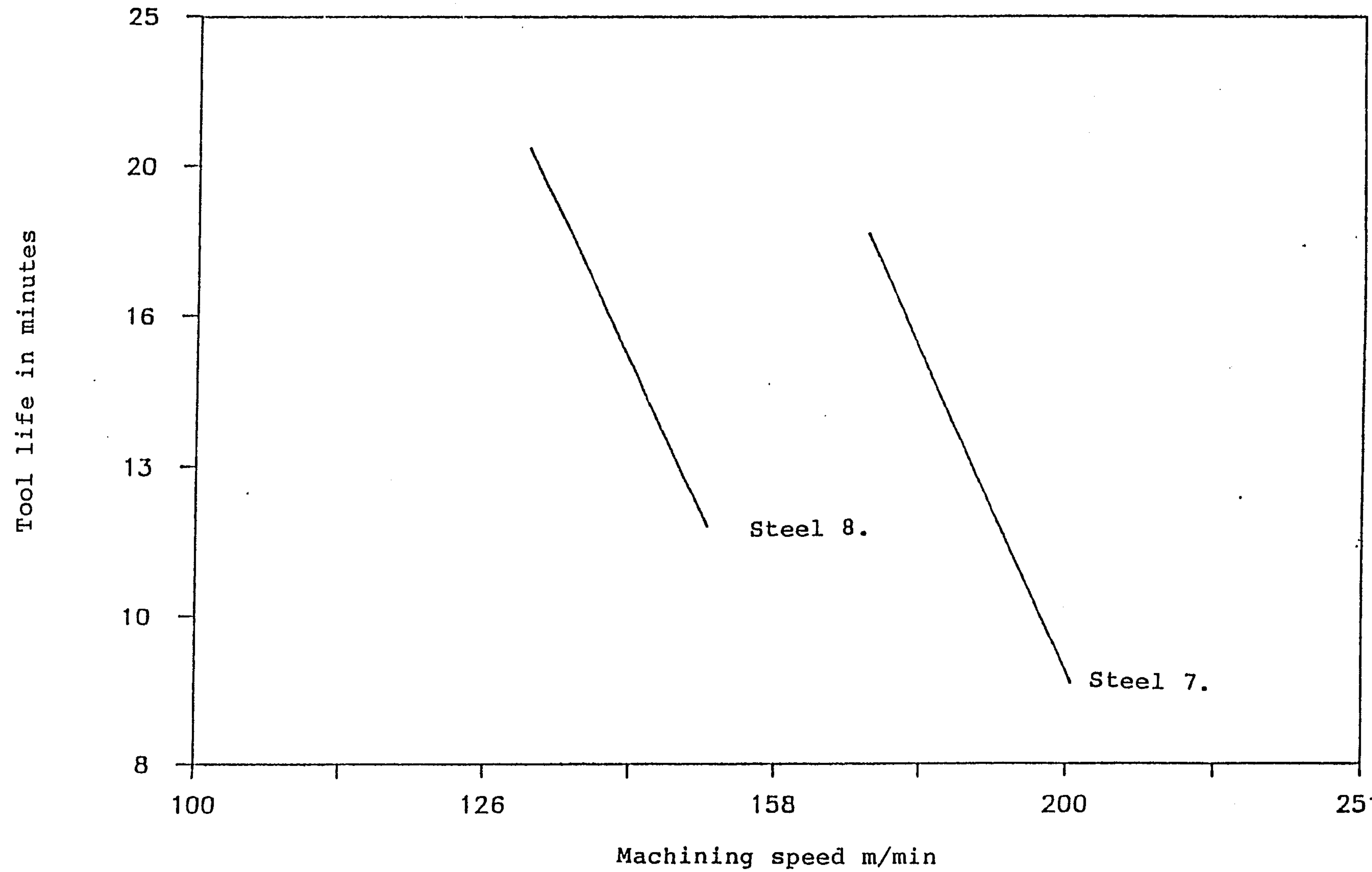
7. Steel as claimed in any one of the claims 1 - 6, **characterized** in that 0.1 - 1.5 kg of calcium is added per ton of molten steel with a lance.

8. Steel as claimed in claim 7, characterized in that the calcium is added as cored wire.

9. Steel as claimed in claim 7, **characterized** in that the calcium is added as capsules or briquettes.

Turning with cemented carbide (ISO 3685-77)

Tool P15, Feed 0.4mm/r, Depth of cut 2.5mm



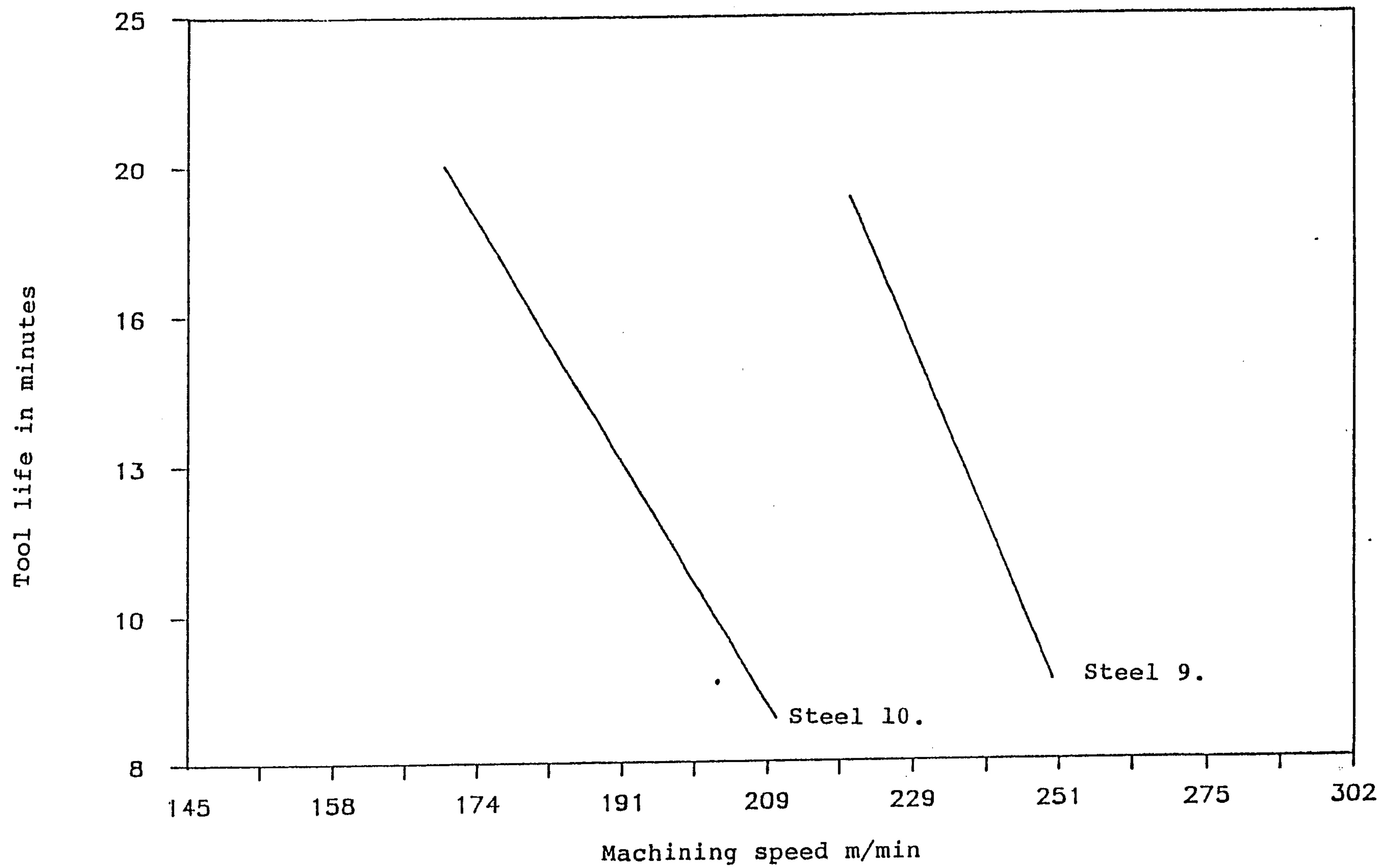
Steel 7 (no Ti), quenched and tempered, hardness 274 HB

Steel 8 (Ti alloying), quenched and tempered, hardness 288 HB

Figure 1. The effect of titanium alloying on the machinability of steel.

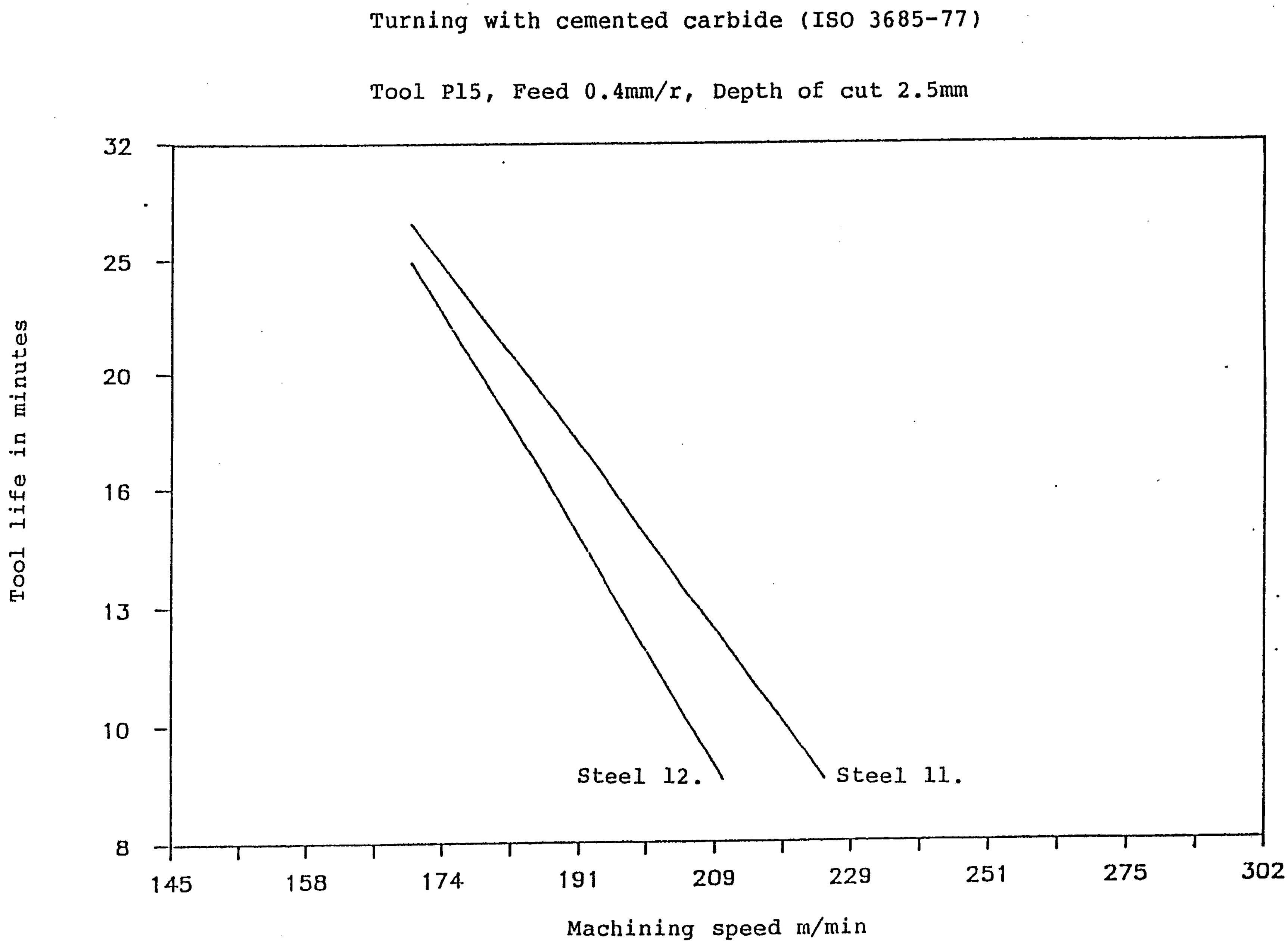
Turning with cemented carbide (ISO 3685-77)

Tool P15, Feed 0.4mm/r, Depth of cut 2.5mm



Steel 9, calcium treated (no Ti), quenched and tempered, hardness 269 HB
Steel 10, (no Ti), quenched and tempered, hardness 253 HB

Figure 2. The effect of calcium treatment on the machinability of steel



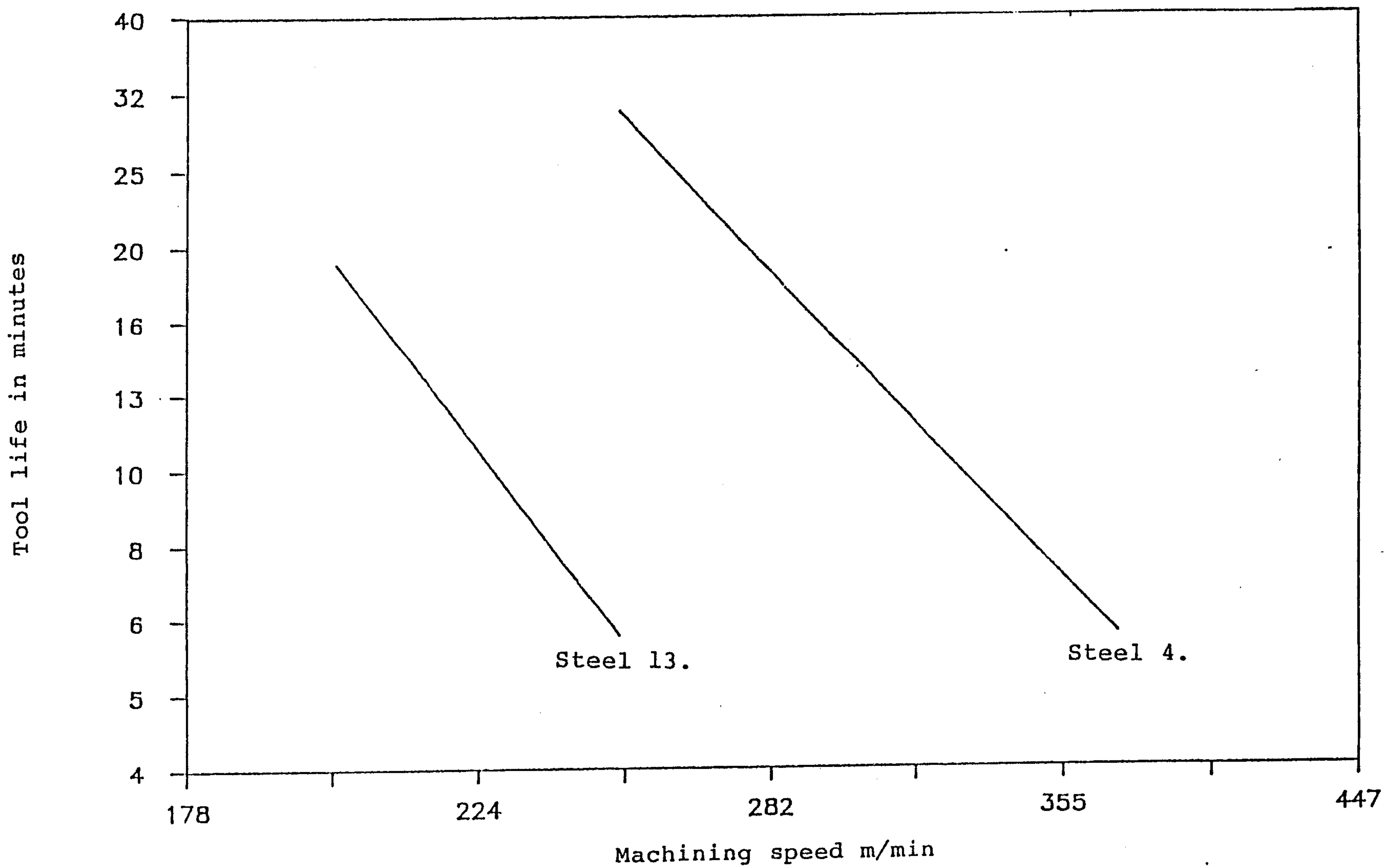
Steel 11, (Ti alloying), quenched and tempered, hardness 259 HB

Steel 12, calcium treated (Ti alloying), quenched and tempered, hardness 257 HB

Figure 3. The machinability of conventional titanium alloyed steel and that of calcium treated titanium alloyed steel.

Turning with cemented carbide (ISO 3685-77)

Tool P15, Feed 0.4mm/r, Depth of cut 2.5mm



Steel 4, calcium treated (no Ti), hot-rolled, hardness 190 HB, steel relating to the invention
Steel 13, calcium treated (Ti alloying), hot-rolled, hardness 192 HB

Figure 4. The machinability of the steel relating to the invention and that of corresponding titanium alloyed calcium treated steel.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 87 85 0292

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	US-A-4 265 660 (GIFLO) * Whole document *	1	C 22 C 38/60 C 22 C 38/00
Y	US-A-2 388 214 (MURPHY) * Whole document *	1	
A	US-A-3 634 073 (CUTTON et al.) * Claims 1,4 *	1	
A	FR-A-2 088 862 (NIPPON KOKAN K.K.) * Claim *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

C 22 C 38

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	19-01-1988	LIPPENS M.H.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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