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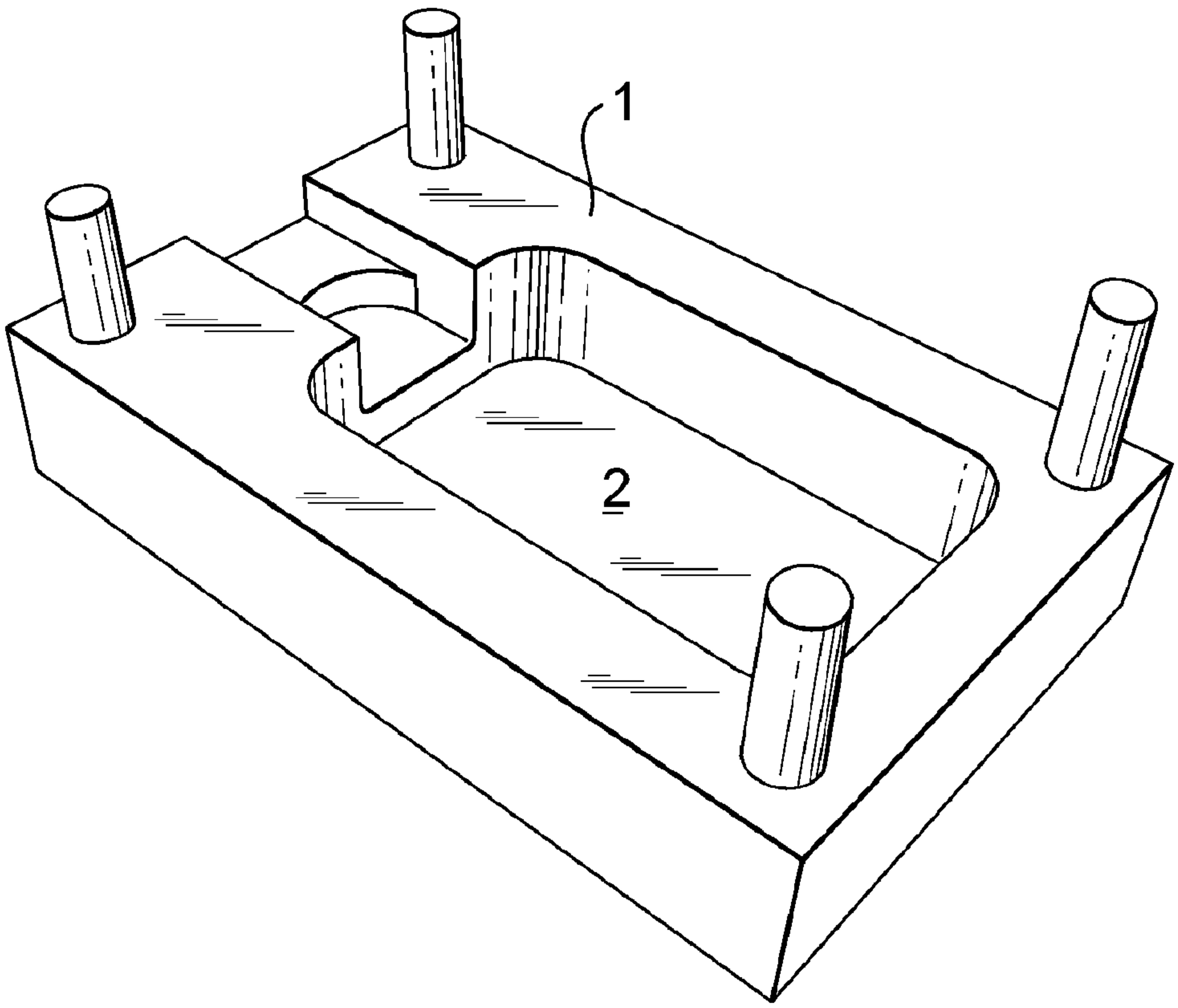
(54) **Titre** : ALLIAGE D'ACIER, SUPPORT OU ELEMENT DE SUPPORT POUR UN OUTIL DE MOULAGE DES MATIERES PLASTIQUES, EBAUCHE RENDUE TENACE PAR TREMPAGE POUR UN SUPPORT OU ELEMENT DE SUPPORT, PROCEDE DE FABRICATION D'UN ALLIAGE D'ACIER

(54) **Title**: STEEL ALLOY, A HOLDER OR A HOLDER DETAIL FOR A PLASTIC MOULDING TOOL, A TOUGH HARDENED BLANK FOR A HOLDER OR HOLDER DETAIL, A PROCESS FOR PRODUCING A STEEL ALLOY



(57) **Abrégé/Abstract**:
A steel alloy suitable for holders and holder details for plastic moulding tools contains in weight-%: 0.08 - 0.19 C, 0.05 - 0.20 N, wherein the total amount of C + N shall satisfy the condition, $0.16 \leq C + N \leq 0.28$, 0.1 - 1.5 Si, 0.1 - 2.0 Mn, 13.0 - 15.4 Cr, 0.01 -

(57) Abrégé(suite)/Abstract(continued):
1.8 Ni, 0.01 1.3 Mo, optionally vanadium up to max. 0.7 V, optionally sulphur in amounts up to max. 0.25 S and optionally also calcium and oxygen in amounts up to max. 0.01 (100 ppm) Ca and max. 0.01 (100 ppm) O, in order to improve the machinability of the steel, balance iron and unavoidable impurities. The steel alloy shall have a microstructure which in tough hardened condition comprises a martensitic matrix containing up to 30 vol-% ferrite, and having a hardness in its tough hardened condition between 290 - 352 HB. The invention also relates to a process for manufacturing said holders or holder details for plastic moulding tools as well as the holders or holder details themselves.

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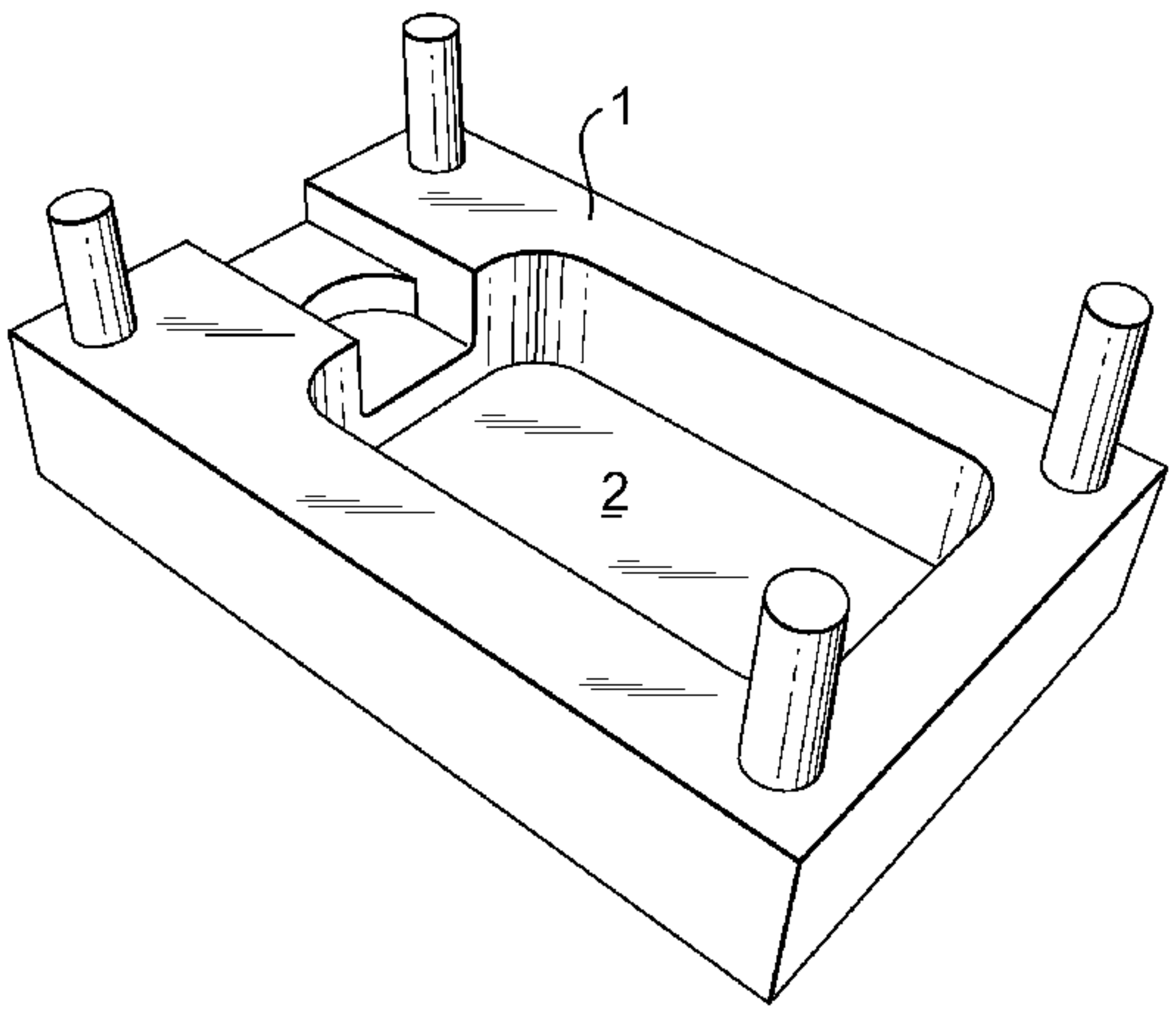
(54) **Title:** STEEL ALLOY, A HOLDER OR A HOLDER DETAIL FOR A PLASTIC MOULDING TOOL, A TOUGH HARDENED BLANK FOR A HOLDER OR HOLDER DETAIL, A PROCESS FOR PRODUCING A STEEL ALLOY



(57) **Abstract:** A steel alloy suitable for holders and holder details for plastic moulding tools contains in weight-%: 0.08 - 0.19 C, 0.05 - 0.20 N, wherein the total amount of C + N shall satisfy the condition, $0.16 \leq C + N \leq 0.28$, 0.1 - 1.5 Si, 0.1 - 2.0 Mn, 13.0 - 15.4 Cr, 0.01 - 1.8 Ni, 0.01 1.3 Mo, optionally vanadium up to max. 0.7 V, optionally sulphur in amounts up to max. 0.25 S and optionally also calcium and oxygen in amounts up to max. 0.01 (100 ppm) Ca and max. 0.01 (100 ppm) O, in order to improve the machinability of the steel, balance iron and unavoidable impurities. The steel alloy shall have a microstructure which in tough hardened condition comprises a martensitic matrix containing up to 30 vol-% ferrite, and having a hardness in its tough hardened condition between 290 - 352 HB. The invention also relates to a process for manufacturing said holders or holder details for plastic moulding tools as well as the holders or holder details themselves.

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A STEEL ALLOY, A HOLDER OR A HOLDER DETAIL FOR A PLASTIC MOULDING TOOL, A TOUGH HARDENED BLANK FOR A HOLDER OR HOLDER DETAIL, A PROCESS FOR PRODUCING A STEEL ALLOY.

TECHNICAL FIELD

The invention relates to a steel alloy and particularly to a steel alloy for the manufacturing of holders or holder details for plastic moulding tools, plastic and rubber moulds with moderate requirement on polishability, dies for plastic extrusion and also for constructional parts. The invention also concerns holders and holder details manufactured of the steel, as well as blanks made of the steel alloy for the manufacturing of such holders and holder details. The invention also concerns a production method of said steel alloy where improved production economy may be provided.

BACKGROUND OF THE INVENTION

Holders and holder details for plastic moulding tools are employed as clamping and/or framing components for the plastic moulding tool in tool sets, in which tool the plastic product shall be manufactured through some kind of moulding method. Among conceivable holder details there can be mentioned bolster plates and other construction parts as well as heavy blocks with large recesses which can accommodate and hold the actual moulding tool. A steel which is manufactured and marketed by the applicant under the registered trade name RAMAX S® has the following nominal composition in weight-%: 0.33 C, 0.35 Si, 1.35 Mn, 16.6 Cr, 0.55 Ni, 0.12 N, 0.12 S, balance iron and impurities from the manufacturing of the steel. The closest comparable standardized steel is AISI 420F. Steels of this type have an adequate corrosion resistance, and are hardened and tempered to have a martensitic microstructure.

In recent years several steels have been developed which seeks to improve the features of steels for this field of application. Particularly, the corrosion resistance, ductility, hardenability and machinability are properties which have gained extensive focus in order to improve the features of the steels. These steels contain lower amounts of carbon and chromium than the above steels. Furthermore, copper is added and the amount of silicon, manganese and nickel are modified. In order to obtain very low carbon contents, the melt has to be processed in an additional process step. This so called decarburization requires a converter which is equipped with means for blowing gas, normally oxygen or a mixture of oxygen and argon through the melt. This extra process step results in higher production costs.

An example of a steel alloy for use in the manufacture of plastic injection mold base components is disclosed in US 6,358,334. The steel alloy comprises 0.03-0.06 % C, 1.0-1.6 % Mn, 0.01-0.03 % P, 0.06-0.3 % S, 0.25-1.0 % Si, 12.0-14.0 % Cr, 0.5-1.3 % Cu, 0.01-0.1 % V, 0.02-0.08 % N, the rest Fe with trace amounts of ordinarily present elements. Compared to an AISI 420F type of steel, the steel is said to have a beneficial combination of features due to reduced hardness and hardenability, improved ductility, corrosion resistance, hot strength and weldability as well as improved surface quality in hot worked condition.

US 2002/0162614 discloses a maraging steel alloy suitable for the manufacture of a frame construction for plastic moulds, a mould part and a process for production of the steel alloy which is said to obtain an improved machinability, good weldability and high corrosion resistance. The alloy comprises 0.02-0.075 % C, 0.1-0.6 % Si, 0.5-0.25 % S, up to max. 0.04 % P, 12.4-15.2 % Cr, 0.05-1.0 % Mo, 0.2-1.8 % Ni, up to max. 0.15 % V, 0.1-0.45 % Cu, up to max. 0.03 % Al, 0.02-0.08 % N and residual Fe and impurities from the manufacturing.

WO 2006/016043 discloses a martensitic stainless steel for a mould or a mould part for plastic injection moulding. The steel alloy comprises 0.02-0.09 % C, 0.025-0.12 % N, max. 0.34 % Si, max. 0.080 % Al, 0.55-1.8 % Mn, 11,5-16 % Cr, and possibly up to 0.48 % Cu, up to 0.90 % (Mo+W/2), up to 0.90 % Ni, up to 0.090 % V, up to 0.090 % Nb, up to 0.025 % Ti, possibly up to 0.25 % S, the rest Fe and impurities from the manufacturing. The steel is said to obtain an improved weldability, good corrosion resistance, good thermal conductivity and small problems during forging and recycling when compared for example to the steel disclosed in US 6,358,334.

A steel which is manufactured and marketed by the applicant under the registered trade name RAMAX 2® belongs to the recently developed steels. The steel alloy has the following nominal composition: 0.12 % C, 0.20 Si, 0.30 Mn, 0.10 S, 13.4 Cr, 1.60 Ni, 0.50 Mo, 0.20 V, and 0.105 N, the rest Fe and impurities from the manufacturing. The manufacturing of the steel can be performed without any need of a subsequent decarburization step. The steel has excellent machinability, good corrosion resistance and hardenability, uniform hardness in all dimensions and good indentation resistance which result in lower mould production and maintenance costs and is a successful product on the market.

The above mentioned steels have become significantly more expensive to manufacture because the cost of certain alloying elements has increased lately. Furthermore, the low carbon content in some of these steels makes it necessary to perform a decarburization of the melt which results in increased production costs. Therefore it exists a demand for a steel which may be produced at lower alloying costs without any significant reduction in respect of the most important features of a steel for this application, e.g. corrosion resistance, hardenability, machinability and hardness and which can be manufactured without any need of a subsequent decarburization step.

DISCLOSURE OF THE INVENTION

It is an object of the invention to provide a steel alloy and particularly a steel alloy for the manufacturing of holders and holder details for plastic moulding tools, plastic and rubber moulds with moderate requirement on polishability, dies for plastic extrusion and also for constructional parts which can be manufactured at lower alloying costs. This can be achieved with a steel alloy which is c h a r a c t e r i z e d in that it has a chemical composition which contains in weight-%:

0.08 – 0.19 C
$0.16 \leq C + N \leq 0.28$
0.1 – 1.5 Si
0.1 – 2.0 Mn
13.0 – 15.4 Cr
0.01 – 1.8 Ni
0.01 – 1.3 Mo
optionally vanadium up to max. 0.7 V,
optionally S in amounts up to max. 0.25 S and optionally also
Ca and O in amounts up to
max. 0.01 (100 ppm) Ca,
max. 0.01 (100 ppm) O, in order to improve the machinability of the steel,
balance iron and unavoidable impurities, and has a microstructure which in tough hardened condition comprises a martensitic matrix containing up to 30 vol-% ferrite, and having a hardness in its tough hardened condition between 290 – 352 HB.

The invention also aims to provide a steel alloy with an improved machinability since a large part of the manufacturing cost relates to this operation, which is performed by different cutting operations. It is also preferred that the steel alloy of this invention fulfils the following requirements:

- an adequate corrosion resistance,
- a hardness of 290 – 352 HB in tough hardened condition which gives the steel a beneficial combination of hardness and machinability,
- an adequate hardenability, considering the steel shall be possible to be used for the manufacturing of holder blocks made of plates which may have a thickness of up to at least 300 mm and in some cases even up to 400 mm thickness.
- an adequate ductility/toughness,
- a adequate polishability, at least according to a preferred embodiment, in order to able to be used also for moulding tools on which moderate demands are raised as far as polishability is concerned,
- a adequate hot ductility in order avoid extensive machining for removal of defects formed during the hot working operation.

The invention also concerns blanks made of the steel alloy for the manufacturing of such holders and holder details. It is a further object of this invention to provide a production method with improved production economy.

According to the broadest aspect of this invention, the steel alloy for the manufacturing of holders or holder details for plastic moulding tools, plastic and rubber moulds, dies for plastic extrusion and constructional parts of holders and holder details shall have a chemical composition which contains (in weight-%) 0.08 – 0.19 C, $0.16 < C + N < 0.28$, 0.1 – 1.5 Si, 0.1 – 2.0 Mn, 13.0 – 15.4 Cr, 0.01 – 1.8 Ni, 0.01 – 1.3 Mo, max. 0.7 V, max. 0.25 S, max. 0.01 (100 ppm) Ca and max. 0.01 (100 ppm) O, balance iron and unavoidable impurities and containing up to 30 vol-% ferrite in its matrix.

According to a second aspect of the invention an improvement in machinability and further reduction in alloying costs can be obtained if the steel contains (in weight-%) 0.10 –0.15 C, $0.08 < N \leq 0.14$ N, where $0.17 < C + N < 0.25$, 0.7 – 1.2 Si, 0.85 – 1.8 Mn, 13.5 – 14.8 Cr, 0.10 – 0.40 Mo, 0.1 – 0.55 Ni, $0.09 < V \leq 0.20$, the balance being iron and unavoidable impurities, and containing up to 15 vol-% ferrite in its matrix. Preferably, the chemical composition of the steel contains (in weight-%) 0.10 –0.15 C, $0.08 < N \leq 0.14$ N, where $0.17 < C + N < 0.25$, 0.75 – 1.05 Si, 1.35 – 1.55 Mn, 13.6 – 14.1 Cr, 0.15 – 0.25 Mo, 0.30 – 0.45 Ni, $0.09 < V \leq 0.15$, the balance being iron and unavoidable impurities, and containing up to 10 vol-% ferrite in its matrix.

In a variant of the steel, the performed tests have shown that an unexpected improvement in machinability at the same time as a reduction of alloying and production costs can be obtained if the steel alloy has a chemical composition which contains (in weight-%) 0.08 – 0.19 C, 0.16 < C + N < 0.28, 0.75 – 1.05 Si, 1.05 – 1.8 Mn, 13.0 – 15.4 Cr, 0.15 – 0.25 Ni, 0.15 – 0.55 Mo, max. 0.7 V, max. 0.25 S, max. 0.01 (100 ppm) Ca and max. 0.01 (100 ppm) O, balance iron and unavoidable impurities and containing up to 10 vol-% ferrite in its matrix.

As far as the importance of the separate elements and their interaction in the steel are concerned, the following may be considered to apply without binding the claimed patent protection to any specific theory. In this text, always weight-% is referred to when amounts of alloying elements are concerned and volume-% is referred to when the structural composition of the steel is concerned, e.g. carbides, nitrides, carbonitrides, martensite or ferrite, if not otherwise is stated. In this text, M(C,N)-carbides, $M_{23}C_6$-carbides, M_7C_3-carbides etc. refer to carbides and nitrides as well as carbonitrides, if not otherwise stated.

Carbon and nitrogen are elements which have a great importance for the hardness and ductility of the steel. Carbon is also an important hardenability promoting element. Carbon, however, binds chromium in the form of chromium carbides (M_7C_3-carbides) and may therefore impair the corrosion resistance of the steel. The steel therefore may contain max 0.19 % carbon, preferably max 0.15 % carbon and even more preferred max 0.14 % carbon. However, carbon also exists together with nitrogen as a dissolved element in the tempered martensite in order to contribute to the hardness thereof, and acts as an austenite stabilizer. The minimum amount of carbon in the steel shall be 0.08 %, preferably more than 0.09 %. In a preferred embodiment, the carbon content is at least 0.10 %. Nominally the steel contains 0.12% C.

Nitrogen contributes to the provision of a more even, more homogenous distribution of carbides and carbonitrides by affecting the solidification conditions in the alloy system such that larger aggregates of carbides are avoided or are reduced during the solidification. The proportion of chromium rich $M_{23}C_6$-carbides also is reduced in favour of smaller M(C,N), i.e. vanadium-carbides, which has a favourable impact on the ductility/ toughness and the corrosion resistance. Nitrogen contributes to the provision of a more favourable solidification process implying smaller carbides and nitrides, which can be broken up during the working to a more finely dispersed phase. These carbides will also contribute to finer grain size of the steel. Nitrogen also acts as an austenite stabilizer.

From these reasons nitrogen shall exist in an amount of at least 0.05 %, preferably more than 0.08 %, but not more than 0.20 %, preferably max 0.13 %, and even more preferred max 0.11 %. Nominally the steel contains 0.09 % N. At the same time the total amount of carbon and nitrogen shall satisfy the condition $0.16 \leq C + N \leq 0.28$, preferably $0.17 \leq C + N \leq 0.25$. In a preferred embodiment, the sum of carbon and nitrogen shall be at least 0.19 % but suitably max 0.23 %. Nominally, the steel contains 0.21 % (C + N). In the hardened and tempered condition of the steel, nitrogen is substantially dissolved in the martensite in the form of nitrogen-martensite in solid solution and thence contributes to the desired hardness.

In summary, as far as the content of nitrogen is concerned, it can be stated that nitrogen shall exist in the said minimum amount in order to contribute to the desired corrosion resistance by increasing the so called PRE-value of the matrix of the steel, to exist as a dissolved element in the tempered martensite which contributes to the hardness of the martensite and to form carbonitrides, M(C, N), to a desired degree together with carbon, but not exceed said maximum content, maximizing the content of carbon + nitrogen, where carbon is the most important hardness contributor.

Silicon increases the carbon activity of the steel and thence the tendency to precipitate more primary carbides. Also, a positive effect may be obtained in the steels ability to reduce adhesive wear and galling on the cutting tools, and chip breaking properties can be improved by silicon. Moreover, silicon is a ferrite stabilizing element and it shall be balanced in relation to the ferrite stabilizing elements chromium and molybdenum in order for the steel to obtain a desired ferrite content of up to 30 %, thereby providing the steel desired machinability and hot ductility. For the inventive steel however, it appears as if silicon contributes to the improvement in machinability not only by its ferrite promoting feature. At the same time, the steel contains a lower content of carbon than is conventional in steels for the application in question but a higher content than has been suggested in some of the recently developed steels mentioned above. The steel therefore shall contain at least 0.1 % Si, preferably more than 0.6 %, and even more preferred at least 0.7 % Si. Generally the rule shall apply that the ferrite stabilizing elements shall be adapted to the austenite stabilizing ones in order to obtain the desired formation of ferrite in the steel. The maximum content of silicon is 1.5 %, preferably max 1.2 %. A preferred silicon content is 0.75 – 1.05 %. Nominally the steel contains 0.90 % silicon.

Manganese is an element which promotes hardenability, which is a favourable effect of manganese and can also be employed for sulphur refining by forming manganese sulphides in the steel which also promotes the machinability. In a preferred embodiment, the inventive steel shall have a hardenability which makes bars at larger dimensions possible to be hardened by cooling in air, thereby eliminating the need of subsequent flattening of the hardened bars. Manganese therefore shall exist in a minimum amount of 0.1 %, preferably at least 0.85 % and even more preferred at least 1.05 %. Manganese, however has a segregation tendency together with phosphorous which can give rise to tempering-embrittlement wherefore the content of phosphorous shall be controlled to not exceed impurity level. Manganese also is an austenite stabilizing element. Manganese therefore must not exist in an amount exceeding 2.0 %, preferably max.1.8 % and even more preferred max. 1.6 %. In a preferred embodiment, the manganese content is 1.35 – 1.55 % and even more preferred 1.40 – 1,45 %. Nominally the steel contains 1.45 % Mn.

Chromium is an important alloying element and is essentially responsible for provision of the stainless character of the steel, which is an important feature of holders and holder details for plastic moulding tools, as well as for the plastic moulding tool itself, which often is used in damp environments, which may cause less corrosion resistant steels to rust.

Chromium also is the most important hardenability promoting element of the steel. However, no substantial amounts of chromium are bound in the form of carbides, because the steel has comparatively low carbon content, wherefore the steel can have a chromium content as low as 13.0 % and nevertheless get a desired corrosion resistance. Preferably the steel, however, contains at least 13.5 %. The upper limit is determined in the first place by cost reasons, reduced hardness due to carbide precipitation, and the risk for chromium segregations. The steel therefore must not contain more than max. 15.4 % Cr, preferably max. 14.8 % Cr, and even more preferred max 14.5 % Cr. Chromium is a ferrite stabilizer and, if present in amounts within the upper ranges of the defined interval, it may preferably be combined with a high carbon content, typically 0.14 – 0.18 % C. However, according to a preferred embodiment, the chromium content is kept at more moderate amounts, typically 13.6 – 14.1 %. Nominally, the steel contains 13.9 % Cr.

Nickel is an element which improves the toughness of the steel. Further it is beneficial for hardenability. Therefore, nickel shall exist in the steel in a minimum amount of 0.01 %, preferably at least 0.15 %. For cost reasons and because nickel acts as an austenite stabiliser, the content should be limited to max. 1.8 %, preferably to max. 1.5 %.

In order to further reduce the costs of alloying elements, the nickel content may be reduced even further, to an interval of 0.15 – 0.55 %, preferably 0.20 – 0.50 % and even more preferred 0.30 -0.45 % Ni. In order for this embodiment to obtain the desired hardenability, the low nickel content is combined with a manganese content of 1.05 – 1.8 % Mn, preferably 1.35 – 1.55 % Mn, possibly also with a silicon content of 0.75 – 1.05 % Si. Nominally the steel contains 0.36 Ni.

In a variant of the steel, the steel does not contain any intentionally added vanadium. However, in a preferred embodiment, the steel of the invention also contains an active content of vanadium in order to bring about a secondary hardening through precipitation of secondary carbides in connection with the tempering operation, wherein the tempering resistance is increased. Vanadium, when present, also acts as a grain growth inhibitor through the precipitation of M(N,C)-carbides which is beneficial. If the content of vanadium is too high, however, there will be formed large primary M(N,C)-carbides during the solidification of the steel, which will not be dissolved during the hardening procedure. For the achievement of the desired secondary hardening and to avoid grain growth, the vanadium content shall be at least 0.05 % V, preferably 0.07 % V and even more preferred more than 0.09 % V. The upper amount of vanadium is determined primarily to avoid the formation of large, undissolvable primary carbides in the steel and for that reason the content of vanadium should be max. 0.7 % V, preferably max 0.25 % V and even more preferred max. 0.20 % V, but may be reduced even further to max. 0.15 % V. The nominal content is 0.10 % V.

Preferably, the steel also contains an active content of molybdenum, e.g. at least 0.05 %, preferably at least 0.10%, in order to give a hardenability promoting effect. Molybdenum also promotes the corrosion resistance. From cost reasons though, it is desirable to minimise molybdenum, but still both corrosion resistance and hardenability shall be sufficient.

When tempering, molybdenum also contributes to increasing the tempering resistance of the steel, which is favourable. On the other hand, a too high content of molybdenum may give rise to an unfavourable carbide structure by causing a tendency to precipitation of grain boundary carbides and segregations and for that reason the maximum amount of molybdenum is set to 1.3 %. In summary, the steel shall contain a balanced content of molybdenum in order to take advantage of its favourable effects but at the same time avoid those ones which are unfavourable. A suitable molybdenum content is between 0.10 – 0.40 %. In a preferred embodiment the molybdenum is

0.15 – 0.25 % Mo. Nominally, the steel contains 0.20% Mo.

Normally, the steel does not contain tungsten in amounts exceeding the impurity level, but may possibly be tolerated in amounts up to 1 %.

Copper promotes the corrosion resistance and hardness of the steel and would for that reason be a suitable alloying element in the steel. However, copper impair the hot ductility even in low amounts and it is impossible to extract copper from steel once it's added. This fact contributes drastically to impair the possibility to internally recycling the steel in the mill. Logistic scrap handling must in such cases be built up to also avoid raised Cu contents in grades not tolerant to high Cu contents. This is well documented for e.g. hot work tool steels where ductility at ambient or elevated temperatures at the using in a specific application are negatively affected (ref. to Ernst et al. Impact of scrap use on the properties of hot-work tool steels, European Commission technical steel research, EUR20906, 2003). For that reason, copper shall be tolerated only as unavoid-able and unintentionally added element from the scrap. The maximum amount of cupper in the steel is 0.40 %, preferably 0.25 % and even more preferred max. 0.15 % Cu.

Normally, strong carbide forming alloying elements such as titanium and niobium are also undesired in the steel of the invention since they would impair the toughness and ductility.

The steel of the invention shall be possible to be delivered in its tough-hardened condition, which makes it possible to manufacture large sized holders and mould tools through machining operations. Despite the fact that the hardenability promoting elements nickel and molybdenum are reduced, the steel possesses a hardenability which allows hardening by cooling in air, even of bars with very large dimensions. By cooling in air, distortion and high stresses can be avoided in the steel, which can be released during mould manufacturing. The hardening is carried out through austenitizing at a temperature of 900 – 1100 ºC, preferably at 950- 1025 ºC, or at about 1000 ºC, followed by cooling in oil or in a polymer bath, by cooling in gas in a vacuum furnace, or most preferred in air. The high temperature tempering for the achievement of a tough hardened material with a hardness of 290 – 352 HB which is suitable for machining operations, is performed at a temperature of 510 – 650 ºC, preferably at 540 – 620 ºC, for at least one hour, preferably through double tempering; twice for two hours.

The steel may, according to a preferred embodiment, also contain an active content of sulphur, possibly in combination with calcium and oxygen, in order to improve the machinability of the steel in its tough hardened condition. In order to obtain further improvement in terms of machinability, the steel should contain at least 0.10 % S if the steel does not also contain an intentionally added amount of calcium and oxygen. The maximum sulphur content of the steel is 0.25 %, preferably max 0.15 %, when the steel is intentionally alloyed with a content of sulphur. A suitable sulphur content in this case may be 0.13 %. Also a non-sulphurized variant of the steel can be conceived. This variant will obtain a better polishability. In this case the steel does not contain sulphur above impurity level, and nor does the steel contain any active contents of calcium and/or oxygen.

It is thus conceivable that the steel may contain 0.035 – 0.25 % S in combination with 3 – 100 ppm Ca, preferably 5 – 75 ppm Ca, suitably max. 40 ppm Ca, and 10 – 100 ppm O, wherein said calcium, which may be supplied as silicon-calcium, CaSi, in order to globulize existing sulphides to form calcium sulphides, counteracts that the sulphides get a non-desired, elongated shape, which might impair the ductility.

According to the broadest aspect of this invention, an improvement in machinability in hardened and tempered condition can be achieved if the steel contains up to 30 vol-% ferrite. The performed tests have also shown that the inventive steel meets the requirements set for its intended use. Further, the steel is possible to produce at lower alloying and production costs.

The performed tests have also revealed, very surprisingly, that in a variant of the steel an improved machinability can be obtained even at very low levels, i.e. up to about 10 %. In this variant of the steel, the silicon content is 0.75 – 1.05 %. Particularly molybdenum, which has become expensive, is kept at low levels, and a preferred molybdenum content is 0.15 – 0.25 %. Also nickel has become expensive and shall therefore be kept at low levels. A suitable nickel content is 0.15 – 0.55 %, preferably 0.30 – 0.45 %, which preferably is combined with a manganese content of 1.05 – 1.8 % Mn, preferably 1.35 – 1.55 % Mn, in order to obtain the desired hardenability of the steel. Nominally the steel contains 0.36 Ni, 1.45 Mn and 0.90 Si. In order to further reduce the alloying costs it is possible to reduce the vanadium content to 0.10 – 0.15 % and still obtain an effect as grain growth inhibitor and adequate ductility/toughness.

Further characteristics, aspects and features of the steel according to the invention, and its usefulness for the manufacturing of holders and moulding tools, will be explained more in detail in the following through a description of performed experiments and achieved results.

BRIEF DESCRIPTION OF DRAWINGS

In the following description of performed experiments and achieved results according to the new variant of the steel, reference will be made to the accompanying drawings, in which

Fig. 1	shows a holder block of a typical design, which can be manufactured of the steel according to the invention,
Fig. 2A	is a chart showing the hardness of a first set of steels, produced in the form of so called Q-ingots (50 kg laboratory heats), after hardening but before tempering, versus the austenitizing temperature at a holding time of 30 min,
Fig. 2B	shows corresponding graphs for another number of tested steels manufactured as Q-ingots,
Fig. 2C	shows corresponding graphs for yet another number of tested steels manufactured as Q-ingots,
Fig. 2D	shows a corresponding graph for a tested steel produced at 60 tons production scale (so called DV-heat),
Fig. 3	shows tempering curves for those steels which have been hardened from 1000 ºC,
Fig. 4A - B	is a chart which showing hardenability curves for the steels,
Fig. 5A - D	are bar charts illustrating results from machinability testing of steels, manufactured at laboratory scale and production scale,
Fig. 6A, B	is a chart which shows the hot ductility for a number of steels,
Fig. 7	is a photo showing the microstructure for a preferred embodiment of the new variant of the steel, and
Fig. 8	shows polarisation curves for the inventive steel and some reference steels.

EXAMINATION OF STEELS

Fig. 1 shows a holder block 1 of a typical design, which shall be possible to be manufactured of the steel according to the invention. In the block1 there is a cavity 2, which shall accommodate a mould tool, usually a plastic moulding tool. The block 1 has considerable dimensions and the cavity 2 is large and deep. Therefore, a number of different requirements are raised on the material according to the invention, i.e. an adequate hardenability with reference to the considerable thickness of the block, and a good ability to be machined by means of cutting tools, such as mill cutters and borers.

<u>Material</u>

Test materials were manufactured both at laboratory scale and production scale. Initially, three rounds with tests on so called Q-ingots (50 kg laboratory heats) were performed (Q9261 – Q9284) followed by one round of tests on materials manufactured at production scale (inventive steel No. 4). Thereafter, a new set of Q-ingots were manufactured (Q9294 – Q9295) and finally a round of tests were performed on materials manufactured at full production scale (inventive steel No. 5).

The compositions of the Q-ingots are shown in Table VI where ingot Q9261 is a reference composition in accordance to reference material No. 1 and Q9271 and Q9283 are reference materials where Q9283 contains a higher amount of S. The Q-ingots were forged to the shape of bars of size 60x40 mm, whereupon the rods were cooled in air to room temperature. The rods were heated to 740°C, cooled at a cooling rate of 15°C/h to 550°C, there from free cooling in air to room temperature.

The compositions of the steels manufactured at production scale are shown in table VIII below. Commercial steels (steels No 1, 2 and 3) for comparison of the features of the inventive steels No. 4 and 5 were obtained from the commercial market and no heat treatment or other treatment was performed to them.

The inventive steel No. 4 was manufactured as a 6 tons full scale test heat and ingots were cast which were manufactured to test pieces by either hot rolling or forging at a temperature of 1240°C. The test pieces were cooled to an isothermal annealing temperature of 650°C and were subjected to an isothermal annealing at the isothermal annealing temperature during 10 h, thereafter cooled in free air to room temperature. The test pieces were then hardened by austenitizing at a temperature of 1000° C, 30 min, and tempered twice during two hours at a temperature of 550 - 620° C.

The inventive steel No 5 was manufactured as a 60 tons full scale test heat was produced in a conventional metallurgical process using an electric arc furnace, processed in a secondary ladle step and cast into ingots. The ingots were forged at a temperature of 1240°C to the shape of bars of size 610x254 mm, 600x100 mm and

610x305 mm respectively. The bars were cooled to an isothermal annealing temperature of 650°C and were subjected to an isothermal annealing at the isothermal annealing temperature during 10 h, thereafter cooled in free air to room temperature. The bars were then hardened by austenitizing at a temperature of 1000° C, 30 min, and tempered twice during two hours at a temperature of 550 - 620° C.

Table VI – Test materials manufactured at laboratory scale; chemical composition in weight-%, balance Fe and unavoidable impurities

Q-ingot No.	C	Si	Mn	S	Cr	Ni	Mo	V	N
Q9261 =ref	0.15	0.09	0.89	0.14	12.9	1.69	0.55	0.22	0.12
Q9262	0.13	0.24	1.10	0.14	13.0	0.84	0.21	0.15	0.10
Q9263	0.13	0.24	1.07	0.13	12.9	0.84	0.21	0.15	0.10
Q9264	0.12	0.26	1.11	0.14	13.0	0.84	0.11	0.14	0.07
Q9271 = ref	0.14	0.12	0.90	0.10	13.2	1.65	0.52	0.24	0.08
Q9272	0.15	0.93	0.90	0.13	14.5	0.96	0.22	0.33	0.08
Q9273	0.13	0.93	0.84	0.12	13.5	0.08	0.21	0.21	0.08
Q9274	0.15	0.75	0.78	0.13	14.7	0.07	0.20	0.20	0.10
Q9275	0.12	0.79	0.90	0.13	15.8	0.95	0.21	0.20	0.06
Q9276	0.07	0.78	0.90	0.11	14.4	0.93	0.20	0.20	0.05
Q9283= Q9271+S	0.12	0.09	1.16	0.13	13.4	1.68	0.53	0.25	0.09
Q9284	0.12	0.87	1.09	0.12	14.8	0.96	0.27	0.22	0.12
Q 9294	0,12	0,89	1,54	0,12	14,0	0,21	0,21	0,11	0,09
Q 9295	0,11	0,94	1,38	0,11	14,4	0,52	0,21	0,10	0,089

Table VIII - Steel composition of examined steels manufactured at production scale; chemical composition in weight-%, balance Fe and unavoidable impurities

	C	Si	Mn	S	Cr	Ni	Mo	V	Cu	N
Steel No 1	0.15	0.18	1.26	0.08	13.6	1.6	0.48	0.20	0.15	0.083
Steel No. 2	0.045	0.40	0.92	0.14	12.8	0.44	0.15	0.049	0.26	0.039
Steel No. 3	0.046	0.43	1.30	0.14	12.7	0.18	0.02	0.032	0.63	0.047
Steel No. 4	0,14	0,89	1,11	0,14	14,3	0,96	0,19	0,15	0.10	0,071
Steel No 5	0.12	0.85	1.44	0.12	13.7	0.37	0.19	0.11	0.037	0.086

Hardness and ferrite content after heat treatment

The hardness versus the austenitizing temperature is shown in Fig. 2A – 2D. It is evident from the charts of these drawings that the reference steels (Q9261, Q9271 and Q9283) have the highest hardness. It is also evident that the hardness increases with increasing austenitizing temperature. However, some of the tested steels of the invention may obtain a hardness which is close to the hardness of the reference steels, but that require that a somewhat higher austenitizing temperature is chosen, i.e. about 1000 °C.

The hardness after tempering of some of the tested steels which have been hardened from 1000°C is shown in Fig. 3. The conclusion can be drawn from the tempering curves that these steels can be tempered down to 34 HRC through tempering in the temperature range 520-600 °C. As is evident from the figure, the inventive steels No. Q9272, Q9273, Q9274 and Q9284 can be tempered at higher temperatures than the other inventive steels and still obtain a high hardness, which is beneficial from a stress relief point of view.

An appropriate hardness of the steel after tough-hardening is about 31 - 38 HRC, (i.e. 290 – 352 HB). In Table VII below, the heat treatments are stated which provide a hardness within the interval to the different steels. The ferrite content has been measured by manual point counting (swe. rutnätsmetoden) after hardening and tempering.

Table VII – Heat treatment for tough-hardening, measured ferrite, percent by volume

Steel No.	Heat treatment	Ferrite content %
Q9261	950°C+580°C/2x2h	0
Q9262	950°C+565°C/2x2h	0
Q9263	950°C+570°C/2x2h	0
Q9264	950°C+565°C/2x2h	0
Q9271	950°C+585°C/2x2h	0
Q9272	950°C+555°C/2x2h	4.5
Q9273	950°C+545°C/2x2h	9
Q9274	950°C+535°C/2x2h	32
Q9275	1000°C+540°C/2x2h	21
Q9276	1000°C+520°C/2x2h	19
Q9283	950°C+585°C/2x2h	0
Q9284	1000°C+590°C/2x2h	2.5
Q9294	1000°C+560°C/2x2h	8.5
Q9295	1000°C+560°C/2x2h	7
Steel No. 4	1000°C+590°C/2x2h	1.5 – 4
Steel No. 5	1000°C+560°C/2h+ 570°C/2h	0.05 – 6.5

Hardenability

The hardness after hardening is shown in the hardenability curves of Fig. 4A and 4B. The austenitizing temperatures are indicated in the figure from which temperatures the samples have been cooled at different rates.

From figure 4A, which shows the hardenability for some of the steels manufactured at laboratory scale, it is evident that steels No. Q9272, Q9294 and Q9295 austenitized at 1000°C have the best hardenability among the inventive steels. These steels have sufficient hardenability in order to be hardened by cooling in air at relatively thick dimensions. The other steels may be used for less thick dimensions. The steels in the figure which shows the lowest hardenability have low Ni content. The best hardenability is obtained by commercial steel No. 1 which is represented by the hardening curves for Q9283 and Q9271.

From figure 4B, which shows the hardenability for the steels manufactured at production scale, it is evident that the inventive steels No 4 and No 5 can obtain a high hardness after hardening which is equal to the commercial steel No.1, (Q9271 in Fig. 4A) and well above the commercial steels No. 2 and No. 3.

Machinability tests performed at laboratory scale

The machinability of the inventive steels which were manufactured at laboratory scale (Q-ingots) where examined and compared to the reference steels Q9261, Q9271 and Q9283. The results are shown in table IX below. It shall be considered that laboratory manufactured steels may contain defects which impair the results.

By face milling with uncoated carbide inserts the time required to wear the flank 0.5 mm were examined. The cutting data were as follows:
Machine type = SEKN 1203AFTN-M14 S25M
Milling cutter = Seco R220.13-0040-12 Ø40 mm, 3 inserts
Cutting speed, vc = 250 m/min
Tooth feed, fz = 0.2 mm/tooth
Axial depth of cut, ap = 2 mm
Radial depth of cut, ae = 22.5 mm
Wear criteria = flank wear 0.5 mm

The result indicated that the inventive steels can obtain equal or better face milling properties as the commercial steels. Q9284 is best among the inventive steels and Q9294 and Q9295 are very good as well.

By drilling with high speed steel, the average number of drilled holes that could be made before the drill were damaged, were examined. The drilling data were as follows:
Drill type: Wedevåg 120 uncoated HSS Ø2 mm
Cutting speed, vc: 26 m/min
Feed rate, f: 0.04 mm/rev.
Drill depth: 5 mm

The result indicated that the inventive steel can obtain better drilling properties than the reference steels.

By end milling with high speed steel the time required to wear the flank 0.15 mm were examined. The drilling data were as follows:
Milling cutter = Sandvik Coromant R216.33-05050-AK13P 1630 Ø5 mm,
Cutting speed, vc = 200 m/min
Tooth feed, fz = 0.05 mm/tooth
Axial depth of cut, ap = 2 mm
Radial depth of cut, ae = 5 mm

Wear criteria = flank wear 0.15 mm

The result indicated that the inventive steel can obtain better end milling properties than the reference steels.

Table IX – Result of machining tests on steels manufactured at laboratory scale

Steel	Hardness (HB)	Face milling	Drilling with HSS	End milling
Q9261	350	n.a.	160*	n.a.
Q9262	348	n.a.	325*	n.a.
Q9271	340	7,5	69	9
Q9272	350	5,9	345	14,9
Q9275	350	8	110	6,3
Q9276	350	1,1	455	9,6
Q9283	330	10,8	178	7
Q9284	320	23,5	507	9,9
Q9294	333	20,1	495	-
Q9295	333	22,2	535	-

* Cutting speed: 22 m/min
n.a. not analysed

When both milling and drilling properties were considered, the results for steels No. Q9284, Q9294 and Q9295 showed that an improvement in machinability can be obtained with a steel according to the invention.

<u>Machinability tests performed at production scale</u>

The machinability of the inventive steels which were manufactured at production scale were examined by different machinig operations and compared to the machinability of some commercial steels.

Fig. 5A shows the result from face milling with coated carbide tools. The cutting data were as follows:
Machine type = Sajo VM 450
Milling cutter = Sandvik Coromant R245-80Q27-12M, Ø80 mm, 6 inserts
Cutting speed, vc = 250 m/min
Tooth feed, fz = 0.2 mm/tooth
Axial depth of cut, ap = 2 mm
Radial depth of cut, ae = 63 mm
Wear criteria = flank wear 0.5 mm

As is evident from Fig. 5A the inventive steel may obtain equal or better face milling properties than the commercial steels. Particularly the inventive steels with somewhat lower hardness than the commercial steels shows superior face milling properties.

Fig. 5B shows the results from cavity milling with coated carbide tools. The cutting data were as follows:
Milling tool: Coromant R200-028A32-12M, Ø 40 mm, l = 145 mm
Carbide grade: Coromant RCKT 1204 MO-PM 4030
Wear criteria: VBmax 0.5 mm
Cutting speed, vc = Varying
Tooth feed, fz = 0.25 mm/tooth
Axial depth of cut, ap = 2 mm
Radial depth of cut, ae = 12 mm

Fig. 5B shows that the inventive steel may obtain equal or better cavity milling properties than the commercial steel No. 2 and 3, and that the inventive steel is superior the commercial steel No. 1.

Fig. 5C shows the result from drilling with high speed steel. It is evident from these tests that the inventive steel can obtain equal or better drilling properties than the commercial steels. The drilling data were as follows:
Drill type: Wedevåg 120 uncoated HSS Ø5 mm
Cutting speed, vc: 26 m/min
Feed rate, f: 0.15 mm/rev.
Drill depth: 12.5 mm

Fig. 5D shows the result from end milling with high speed steel. It is evident from these tests that the inventive steel No.5 can obtain much better end milling properties than the commercial steels. The drilling data were as follows:
Milling cutter: C200 uncoated HSS Ø12 mm
Cutting speed, vc: 70 m/min
Radial depth of cut, ae = 1.2 mm
Axial depth of cut, ap = 18 mm
Tooth feed, fz: 0.14 mm/tooth
Wear criteria = flank wear 0.15 mm

To sum up, the results of the machinability tests are presented in Table X. In the Table, the results for the steels are presented by a value, 1 – 5, where the value 5 represents a very good result and value 1 represents unsatisfying result. The results of steel No. 4 in forged condition are shown at different hardness in accordance to Figs. 5A - C, the hardness in forged condition being 310 HB and 327 HB respectively.

Table X – Result of machining tests on steels manufactured at production scale

Steel	Hardness	Face milling	Drilling	Cavity milling	End milling
No.2	4	3	5	4	3
No.3	3	-	5	3	3
No.1,	4	3	4	2	4
No.1,	5	2	-	2	3
No.4, Hot rolled	3	5	5	5	n.a.
No.4, Forged	3	5	5	5	n.a.
No.4, Forged	4	3	4	3	n.a.
No.5,	4	4	5	5	5

n.a. = not analysed

Hot ductility

The hot ductility of the inventive steel is shown in Figs. 6A and 6B. The curves in the interval of 900 – 1150°C shows the hot ductility obtained for the steel on cooling from the hot work temperature of 1270°C of the test pieces and the curves in the interval of 1150 – 1350°C shows the hot ductility on heating of the test pieces. The inventive steel has shown to have a good hot ductility, both at high and somewhat lower temperatures. The result shows that the inventive steels can be hot worked at high temperatures and also that it can be hot worked down to 900°C which makes it possible to hot work in one step, without reheating.

Microstructure

The microstructure in tough hardened condition of Steel No. 5 is shown in Fig. 7. The microstructure consists of a matrix of martensite 3. Further, the matrix contains approximately 3 % ferrite 1 and some manganese sulphides 2, MnS, can be seen. The tough hardening was performed at an austenitizing temperature of 1000°C, 30 min and tempering at 560°C/2h + 570°C/2h. The manufacturing process included forging and cooling in air. The test piece had a dimension of 610x254 mm obtained by hot rolling.

Corrosion tests

Polarization curves were established for the steels given in Table XI in terms of critical current density, Icr, for the evaluation of the corrosion resistance of the steels. As far as this method of measurement is concerned, the rule is that the lower Icr the better the corrosion resistance.

Table XI – Heat treatment of polarization test specimens. Cooling in vacuum furnace

Q-ingot No.	Heat treatment	Hardness (HRC)	Icr (mA/cm2)
Q9261	950°C+580°C/2x2h	34.6	3.49
Q9262	950°C+565°C/2x2h	35.8	7.23
Q9263	950°C+570°C/2x2h	34.5	6.84
Q9264	950°C+565°C/2x2h	34.3	7.90
Q9271	950+585/2x2h	35.9	1.70
Q9272	950+555/2x2h	36.7	5.40
Q9273	950+545/2x2h	36.5	6.28
Q9274	950+545/2x2h	31.9	4.29
Q9275	1000+540/2x2h	34.2	4.76
Q9276	1000+520/2x2h	35.7	2.53
Q9283	950+585/2x2h	34.3	3.08

The results showed that the steels Q9274, Q9275 and Q9276 had better corrosion resistance than most of the other tested steels, and that Q9276 had best corrosion resistance among the inventive steels, even better than reference materials No. Q9261 and Q9283.

The resistance to general corrosion was investigated by polarisation testing in 0.05 M, H_2SO_4, pH = 1.2, for the inventive steels No. 4 and 5 and the commercial steels No. 1 and No. 3. The polarisation curves are shown in Fig. 7, and it is evident that the inventive steel No. 4 had better resistance to general corrosion than the commercial steel No. 3 and that the inventive steel No. 5 and commercial steel No.3 had approximately the same resistance to general corrosion. Commercial steel No. 1 had the best resistance to general corrosion among the tested steels.

MANUFACTURING PROCESS

In the process for producing a steel alloy for the manufacturing of a holder, holder detail for a plastic moulding tool or a moulding tool, a holder base, a holder detail base or a moulding tool base is manufactured from a steel alloy with a chemical composition according to the invention.

The steel of the invention is manufactured by producing a melt, preferably in an electrical arc furnace, an induction furnace or any other furnace which uses scrap as the main raw material. Possibly, the melt is processed in a secondary ladle step to ensure appropriate conditioning of the steel before the casting process, i.e. alloying of the steel to target analysis, removal of deoxidation products etc. The steel does not need to be treated in a converter to lower the carbon content further. The melt, having a chemical composition according to the invention, is cast into large ingots. The melt may also be cast by continuous casting. It is also possible to cast electrodes of the molten metal and then remelting the electrodes through Electro-Slag-Remelting (ESR). It is also possible to manufacture ingots powder-metallurgically through gas-atomization of the melt to produce a powder, which then is compacted through a technique which may comprise hot isostatic pressing, so called HIPing, or, as an alternative, manufacture ingots through sprayforming.

Said process further comprises the steps of hot working an ingot of said steel alloy at a temperature range of 1100 - 1300°C, preferably 1240 - 1270°C, cooling said steel alloy, preferably in air, from the hot working temperature to a temperature of 50 - 200°C, preferably 50 - 100°C, thereby obtaining a hardening of said steel alloy, followed by tempering twice during 2 hours at a temperature of 510 - 650° C, preferably 540 - 620° C, thereby obtaining a tough hardened blank, and forming the holder base, the holder detail base or moulding tool base by machining operation to a holder, a holder detail for a plastic moulding tool or a moulding tool.

In an alternative process for producing a steel alloy for the manufacturing of a holder, a holder detail for a plastic moulding tool or a moulding tool, a holder base or a holder detail base or a moulding tool base is manufactured from a ingot containing a steel alloy according to the above, said process comprising the steps of hot working an ingot of said steel alloy at a temperature range of 1100 - 1300°C, preferably 1240 - 1270°C. The hot working is followed by a cooling of said steel alloy to an isothermal annealing temperature of 550 - 700°C, preferably 600 - 700°C, where said alloy is subjected to an isothermal annealing at said isothermal annealing temperature during 5 – 10 h. Normally, the isothermal annealing is followed by a cooling of said alloy to room temperature before the steel alloy is subjected to a hardening and tempering operation. The hardening is performed by austenitizing the steel alloy at a temperature of 900 –

1100° C, preferably 950 - 1025° C, and even more preferred at 1000° C, 30 min, and tempering twice during 2 hours at a temperature of 510 - 650° C, preferably 540 - 620° C, thereby obtaining a tough hardened blank, thereafter forming the holder base, the holder detail base or the moulding tool base by machining operation to a holder, a holder detail for a plastic moulding tool or a moulding tool. It is possible that the cooling from the isothermal annealing temperature to room temperature can be excluded, and that the heating to austenitizing temperature may follow directly after the isothermal annealing, but that has yet to be investigated.

PATENT CLAIMS

1. A steel alloy, characterized in that it has a chemical composition which contains in weight-%:
0.08 – 0.19 C
$0.16 \leq C + N \leq 0.28$
0.1 – 1.5 Si
0.1 – 2.0 Mn
13.0 – 15.4 Cr
0.01 – 1.8 Ni
0.01 – 1.3 Mo
optionally vanadium up to max. 0.7 V,
optionally S in amounts up to max. 0.25 S and optionally also
Ca and O in amounts up to
max. 0.01 (100 ppm) Ca,
max. 0.01 (100 ppm) O, in order to improve the machinability of the steel,
balance iron and unavoidable impurities, and has a microstructure which in tough hardened condition comprises a martensitic matrix containing up to 30 vol-% ferrite, and having a hardness in its tough hardened condition between 290 – 352 HB.

2. A steel alloy according to claim 1, characterized in that it contains $0.09 < C \leq 0.15$.

3. A steel alloy according to claim 2, characterized in that it contains 0.10 – 0.13 C.

4. A steel alloy according to claim 1, characterized in that it contains 0.05 – 0.20 N.

5. A steel alloy according to claim 4, characterized in that it contains more than 0.08 N.

6. A steel alloy according to claims 4 or 5, characterized in that it contains max 0.13 N.

7. A steel alloy according to claims 4 or 5, characterized in that it contains max 0.11 N.

8. A steel alloy according to any of claims 1 - 7, c h a r a c t e r i z e d in that the total amount of C + N shall satisfy the condition 0.17 < C + N < 0.25.

9. A steel alloy according to claim 8, c h a r a c t e r i z e d in that the total amount of C + N shall satisfy the condition 0.19 < C + N < 0.23.

10. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it contains more than 0.6 and up to 1.5 Si.

11. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it contains 0.7 – 1.2 Si.

12. A steel alloy according to claim 11, c h a r a c t e r i z e d in that it contains 0.75 – 1.05 Si, preferably 0.84 – 0.95 Si.

13. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it contains 0.85 – 2.0 Mn.

14. A steel alloy according to claim 13, c h a r a c t e r i z e d in that it contains 1.05 – 1.8 Mn.

15. A steel alloy according to claim 14, c h a r a c t e r i z e d in that it contains 1.35 – 1.55 Mn.

16. A steel alloy according to claim 15, c h a r a c t e r i z e d in that it contains 1.40 - 1.45 Mn.

17. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it contains 13.5 – 14.8 Cr.

18. A steel alloy according to claim 17, c h a r a c t e r i z e d in that it contains 13.5 – 14.5 Cr.

19. A steel alloy according to claim 18, c h a r a c t e r i z e d in that it contains 13.6 – 14.1 Cr.

20. A steel alloy according to claim 19, c h a r a c t e r i z e d in that it contains 13.7 – 14.0 Cr.

21. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it contains 0.15 – 1.5 Ni.

22. A steel alloy according to claim 21, c h a r a c t e r i z e d in that it contains 0.15 – 0.55 Ni.

23. A steel alloy according to claim 22, c h a r a c t e r i z e d in that it contains 0.20 – 0.50 Ni, preferably 0.30 – 0.45 Ni.

24. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it contains 0.10 – 0.40 Mo.

25. A steel alloy according to claim 24, c h a r a c t e r i z e d in that it contains 0.15 – 0.25 Mo.

26. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it contains 0.07 – 0.7 V.

27. A steel alloy according to claim 26, c h a r a c t e r i z e d in that it contains more than 0.09 V and up to 0.70 V.

28. A steel alloy according to claim 27, c h a r a c t e r i z e d in that it contains max. 0.25 V.

29. A steel alloy according to claim 28, c h a r a c t e r i z e d in that it contains max. 0.15 V.

30. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it does not contain V above impurity level.

31. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it contains 0.11 – 0.25 S.

32. A steel alloy according to claim 1 or 31, c h a r a c t e r i z e d in that it contains max. 0.15 S.

33. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it contains
0.10 –0.15 C,
$0.08 < N \leq 0.14$ N, where $0.17 \leq C + N \leq 0.25$
0.7 – 1.2 Si,
0.85 – 1.8 Mn,
13.5 – 14.8 Cr,
0.10 – 0.40 Mo,
0.1 – 0.55 Ni,
$0.09 < V \leq 0.20$,
the steel alloy having a martensitic matrix in its tough hardened condition which contains up to 15 vol-% ferrite and having a hardness between 290 – 352 HB.

34. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it contains
0.10 –0.15 C,
$0.08 < N \leq 0.14$ N, where $0.17 \leq C + N \leq 0.25$
0.75 – 1.05 Si,
1.35 – 1.55 Mn,
13.6 – 14.1 Cr,
0.15 – 0.25 Mo,
0.30 – 0.45 Ni,
$0.09 < V \leq 0.15$,
the steel alloy having a martensitic matrix in its tough hardened condition containing up to 10 vol-% ferrite, and having a hardness between 290 – 352 HB.

35. A steel alloy according to claim 1, c h a r a c t e r i z e d in that it contains
0.75 – 1.05 % Si,
1.05 – 1.8 Mn,
0.15 – 0.25 % Mo,
0.15 – 0.55 Ni,
the steel alloy having a martensitic matrix in its tough hardened condition containing up to 10 vol-% ferrite, and having a hardness between 290 – 352 HB.

36. A steel alloy according to claim 35, c h a r a c t e r i z e d in that it contains 0.30 – 0.45 % Ni.

37. A steel alloy according to claim 35, c h a r a c t e r i z e d in that it contains 1.30 – 1.65 Mn.

38. A steel alloy according to claim 35, c h a r a c t e r i z e d in that it contains 0.10 – 0.15 % V.

39. A steel alloy according to claim 35, c h a r a c t e r i z e d in that the matrix contains 0.05 – 6.5 vol-% ferrite.

40. A process for producing a holder base or a holder detail base or a moulding tool base for a holder or holder detail for plastic moulding tool or a moulding tool, said process comprising the steps of manufacturing a steel alloy with a chemical composition according to any of claims 1 -39,
hot working an ingot of said steel alloy at a temperature range of 1100 - 1300°C, preferably 1240 - 1270°C,
cooling said steel alloy, thereby obtaining an hardening of said steel,
tempering said steel alloy twice during 2 hours at a temperature of 510 - 650° C, preferably 540 - 620° C.

41. A process for producing a holder base or a holder detail base or a moulding tool base for a holder or holder detail for plastic moulding tool or a moulding tool, said process comprising the steps of manufacturing a steel alloy with a chemical composition according to any of claims 1 -37,
hot working an ingot of said steel alloy at a temperature range of 1100 - 1300°C, preferably 1240 - 1270°C,
cooling said steel alloy to a isothermal annealing temperature of 550 - 700°C, preferably 600 - 700°C,
subjecting said steel alloy to an isothermal annealing at said isothermal annealing temperature during 5 – 10 h,
hardening said steel alloy by austenitizing at a temperature of 900 – 1100° C, preferably 950 - 1025° C, and even more preferred at 1000° C, 30 min, and tempering twice during 2 hours at a temperature of 510 - 650° C, preferably 540 - 620° C.

42. The process of claim 40 or 41, characterised in that said steel alloy is produced by using scrap as the main raw material and melting said scrap in a furnace, preferably an electric arc furnace.

43. The process of claim 40 or 41, wherein said step of hot working said alloy comprises the steps of forging and/or rolling said steel alloy.

44. A holder or holder detail for a plastic moulding tool or a die for plastic extrusion or a constructional part, c h a r a c t e r i z e d in that it is manufactured from a steel ingot with a chemical composition which contains in weight-%:
0.08 – 0.19 C
$0.16 \leq C + N \leq 0.28$
0.1 – 1.5 Si
0.1 – 2.0 Mn
13.0 – 15.4 Cr
0.01 – 1.8 Ni
0.01 – 1.3 Mo
optionally vanadium up to max. 0.7 V,
optionally S in amounts up to max. 0.25 S and optionally also
Ca and O in amounts up to
max. 0.01 (100 ppm) Ca,
max. 0.01 (100 ppm) O, in order to improve the machinability of the steel,
balance iron and unavoidable impurities, said manufacturing comprising the steps of hot working an ingot of said steel alloy at a temperature range of 1100 - 1300°C, preferably 1240 - 1270°C,
cooling said steel alloy, thereby obtaining an hardening of said steel,
tempering said steel alloy twice during 2 hours at a temperature of 510 - 650° C, preferably 540 - 620° C, thereby obtaining a microstructure having a martensitic matrix containing up to 30 vol-% ferrite, and having a hardness between 290 – 352 HB, and forming said holder or holder detail for a plastic moulding tool by machining operation.

45. A holder or holder detail for a plastic moulding tool or a die for plastic extrusion or a constructional part, c h a r a c t e r i z e d in that it is manufactured from a steel ingot with a chemical composition which contains in weight-%:
0.08 – 0.19 C
$0.16 \leq C + N \leq 0.28$

0.1 – 1.5 Si
0.1 – 2.0 Mn
13.0 – 15.4 Cr
0.01 – 1.8 Ni
0.01 – 1.3 Mo
optionally vanadium up to max. 0.7 V,
optionally S in amounts up to max. 0.25 S and optionally also
Ca and O in amounts up to
max. 0.01 (100 ppm) Ca,
max. 0.01 (100 ppm) O, in order to improve the machinability of the steel,
balance iron and unavoidable impurities, said manufacturing comprising the steps of
hot working an ingot of said steel alloy at a temperature range of 1100 - 1300°C, preferably 1240 - 1270°C,
cooling said steel alloy to a isothermal annealing temperature of 550 - 700°C, preferably 600 - 700°C,
subjecting said steel alloy to an isothermal annealing at said isothermal annealing temperature during 5 – 10 h,
hardening said steel alloy by austenitizing at a temperature of 900 – 1100° C, preferably 950 - 1025° C, and even more preferred at 1000° C, 30 min, and
tempering twice during 2 hours at a temperature of 510 - 650° C, preferably 540 - 620° C, thereby obtaining a microstructure having a martensitic matrix containing up to 30 vol-% ferrite, and having a hardness between 290 – 352 HB, and
forming said holder or holder detail for a plastic moulding tool by machining operation.

46. A tough hardened blank for a holder or holder detail for a plastic moulding tool, c h a r a c t e r i z e d in that it is manufactured from a steel ingot with a chemical composition which contains in weight-%:
0.08 – 0.19 C
$0.16 \leq C + N \leq 0.28$
0.1 – 1.5 Si
0.1 – 2.0 Mn
13.0 – 15.4 Cr
0.01 – 1.8 Ni
0.01 – 1.3 Mo
optionally vanadium up to max. 0.7 V,
optionally S in amounts up to max. 0.25 S and optionally also

Ca and O in amounts up to
max. 0.01 (100 ppm) Ca,
max. 0.01 (100 ppm) O, in order to improve the machinability of the steel,
balance iron and unavoidable impurities, said manufacturing comprising the steps of hot working an ingot of said steel alloy at a temperature range of 1100 - 1300°C, preferably 1240 - 1270°C,
cooling said steel alloy, thereby obtaining an hardening of said steel,
tempering said steel alloy twice during 2 hours at a temperature of 510 - 650° C, preferably 540 - 620° C, thereby obtaining a microstructure having a martensitic matrix containing up to 30 vol-% ferrite, and having a hardness between 290 – 352 HB.

47. A tough hardened blank for a holder or holder detail for a plastic moulding tool, c h a r a c t e r i z e d in that it is manufactured from a steel ingot with a chemical composition which contains in weight-%:
0.08 – 0.19 C
$0.16 \leq C + N \leq 0.28$
0.1 – 1.5 Si
0.1 – 2.0 Mn
13.0 – 15.4 Cr
0.01 – 1.8 Ni
0.01 – 1.3 Mo
optionally vanadium up to max. 0.7 V,
optionally S in amounts up to max. 0.25 S and optionally also
Ca and O in amounts up to
max. 0.01 (100 ppm) Ca,
max. 0.01 (100 ppm) O, in order to improve the machinability of the steel,
balance iron and unavoidable impurities, said manufacturing comprising the steps of hot working an ingot of said steel alloy at a temperature range of 1100 - 1300°C, preferably 1240 - 1270°C,
cooling said steel alloy to a isothermal annealing temperature of 550 - 700°C, preferably 600 - 700°C,
subjecting said steel alloy to an isothermal annealing at said isothermal annealing temperature during 5 – 10 h,
hardening said steel alloy by austenitizing at a temperature of 900 – 1100° C, preferably 950 - 1025° C, and even more preferred at 1000° C, 30 min, and tempering twice during 2 hours at a temperature of 510 - 650° C, preferably 540 -

620° C, thereby obtaining a microstructure having a martensitic matrix containing up to 30 vol-% ferrite, and having a hardness between 290 – 352 HB.

Fig. 1

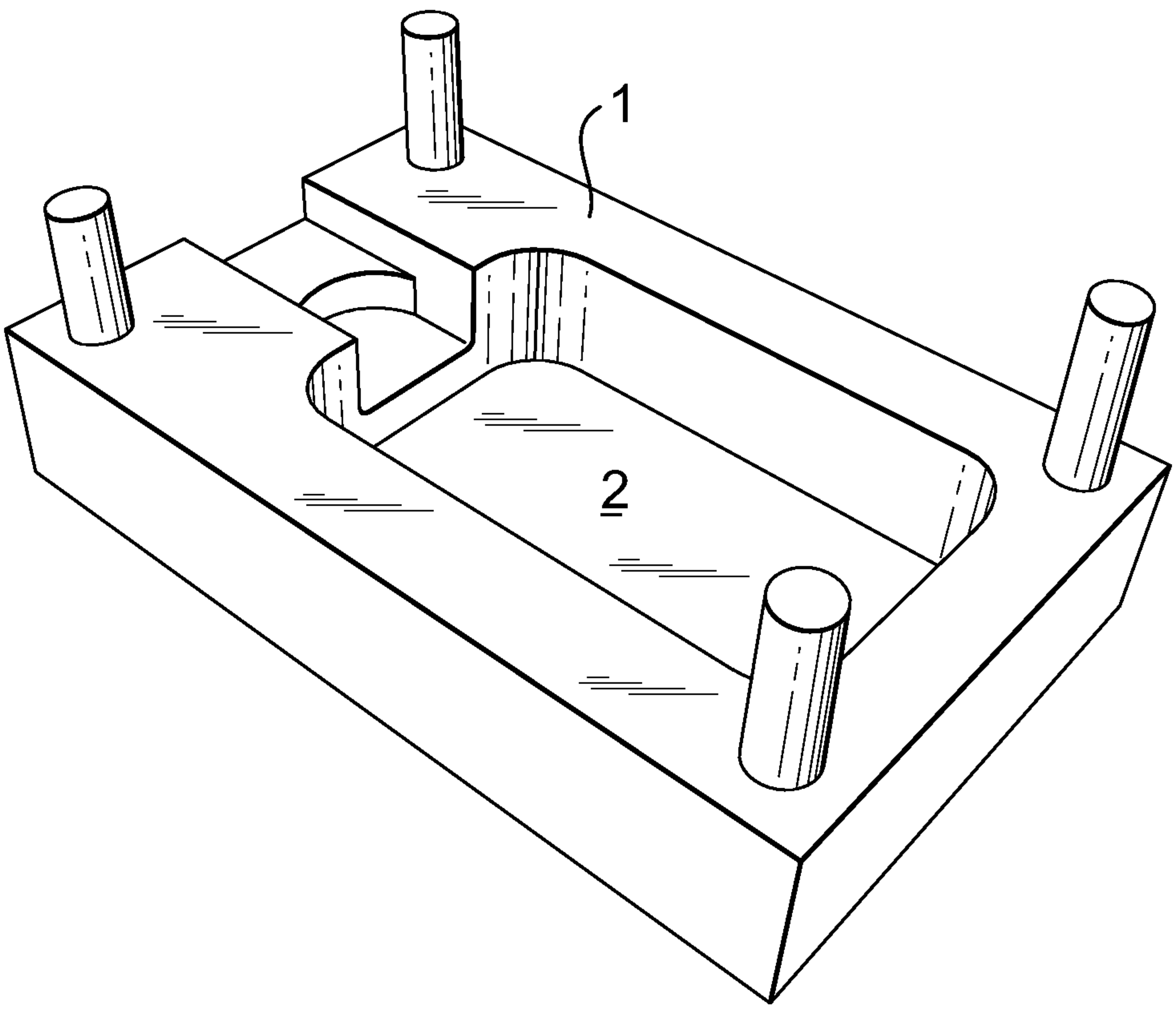


Fig.2A

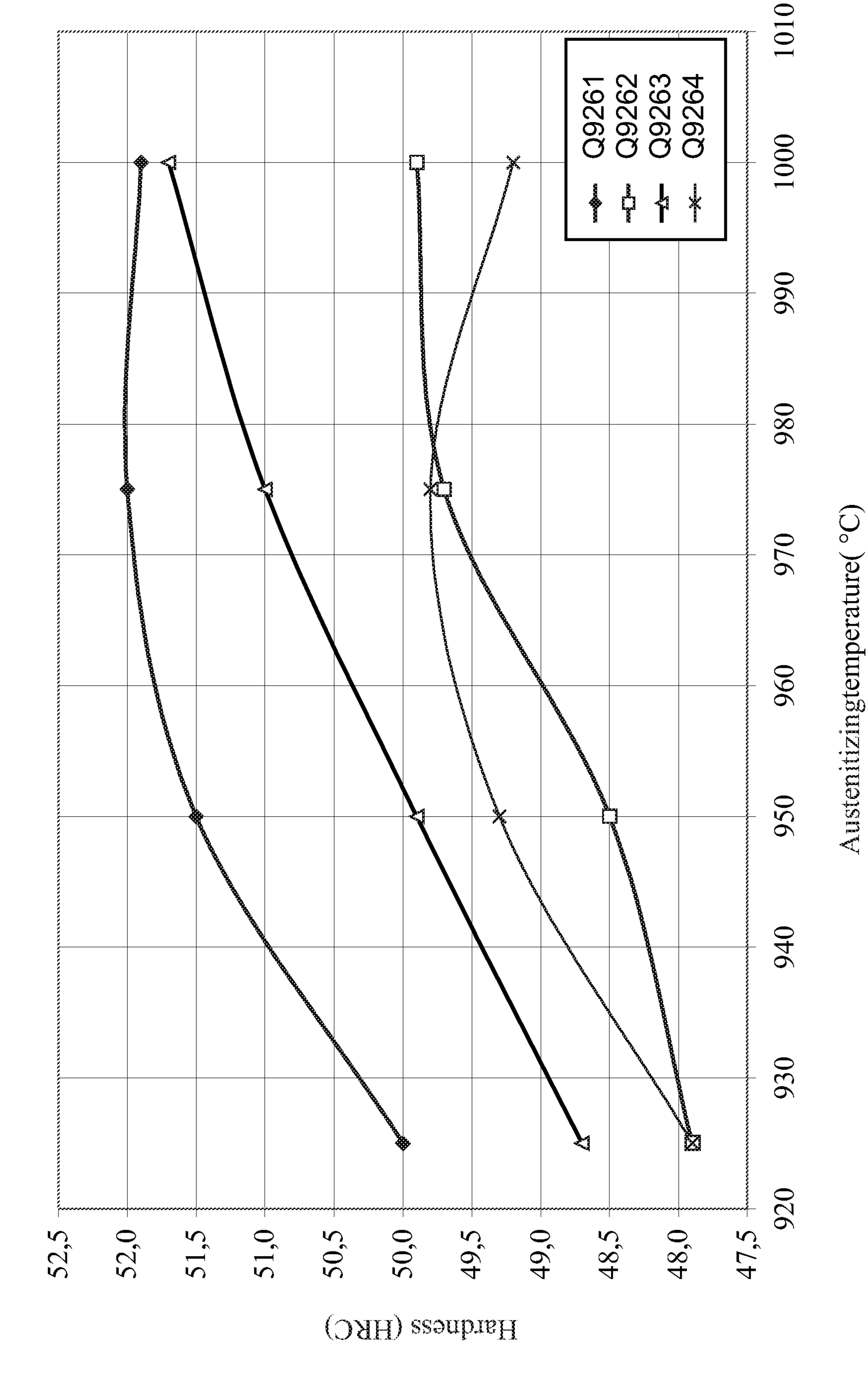

Hardness (HRC)
52,5
52,0
51,5
51,0
50,5
50,0
49,5
49,0
48,5
48,0
47,5
920
930
940
950
960
970
980
990
1000
1010
Austenitizingtemperature(°C)
Q9261
Q9262
Q9263
Q9264

Fig.2B

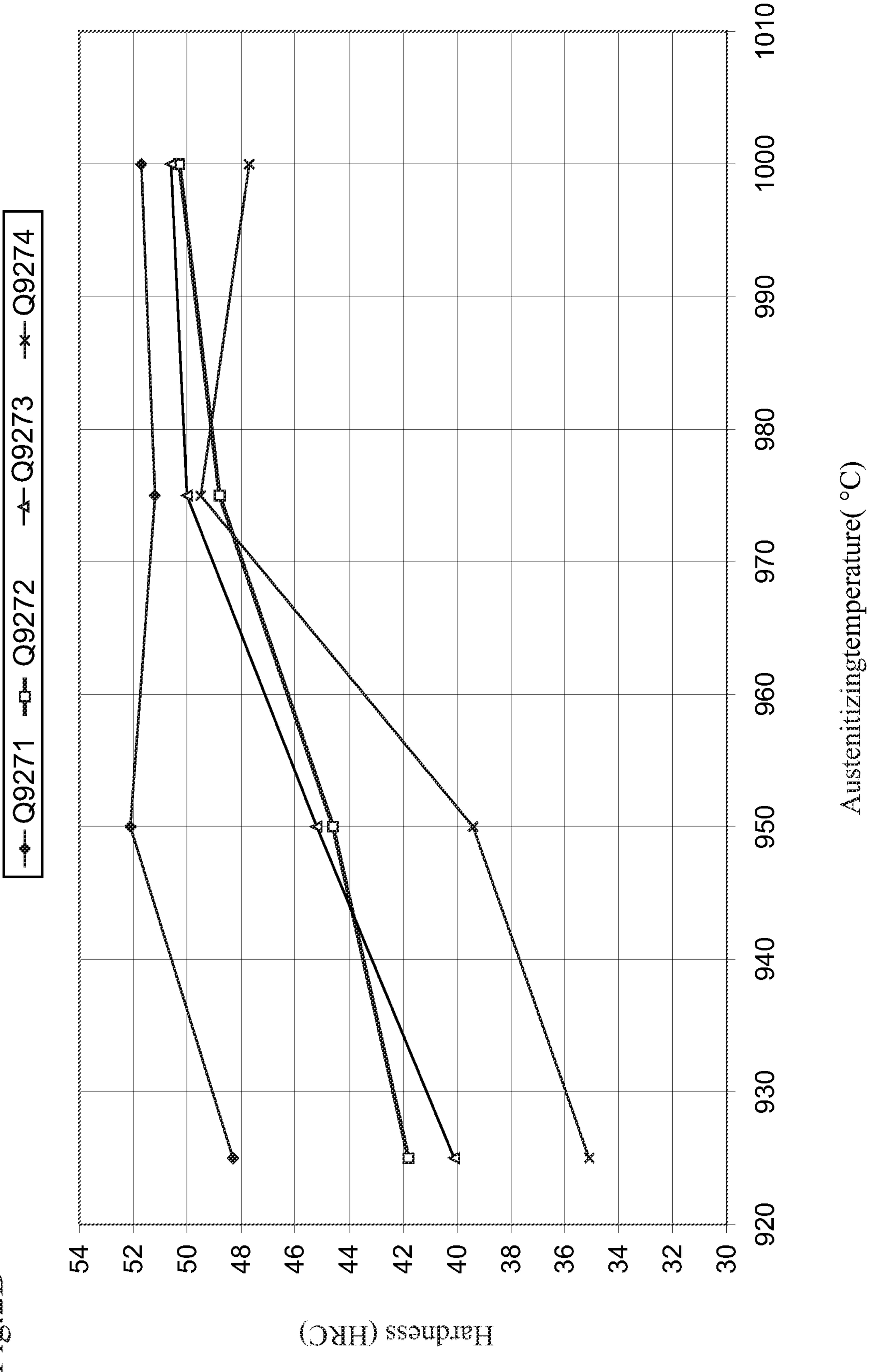
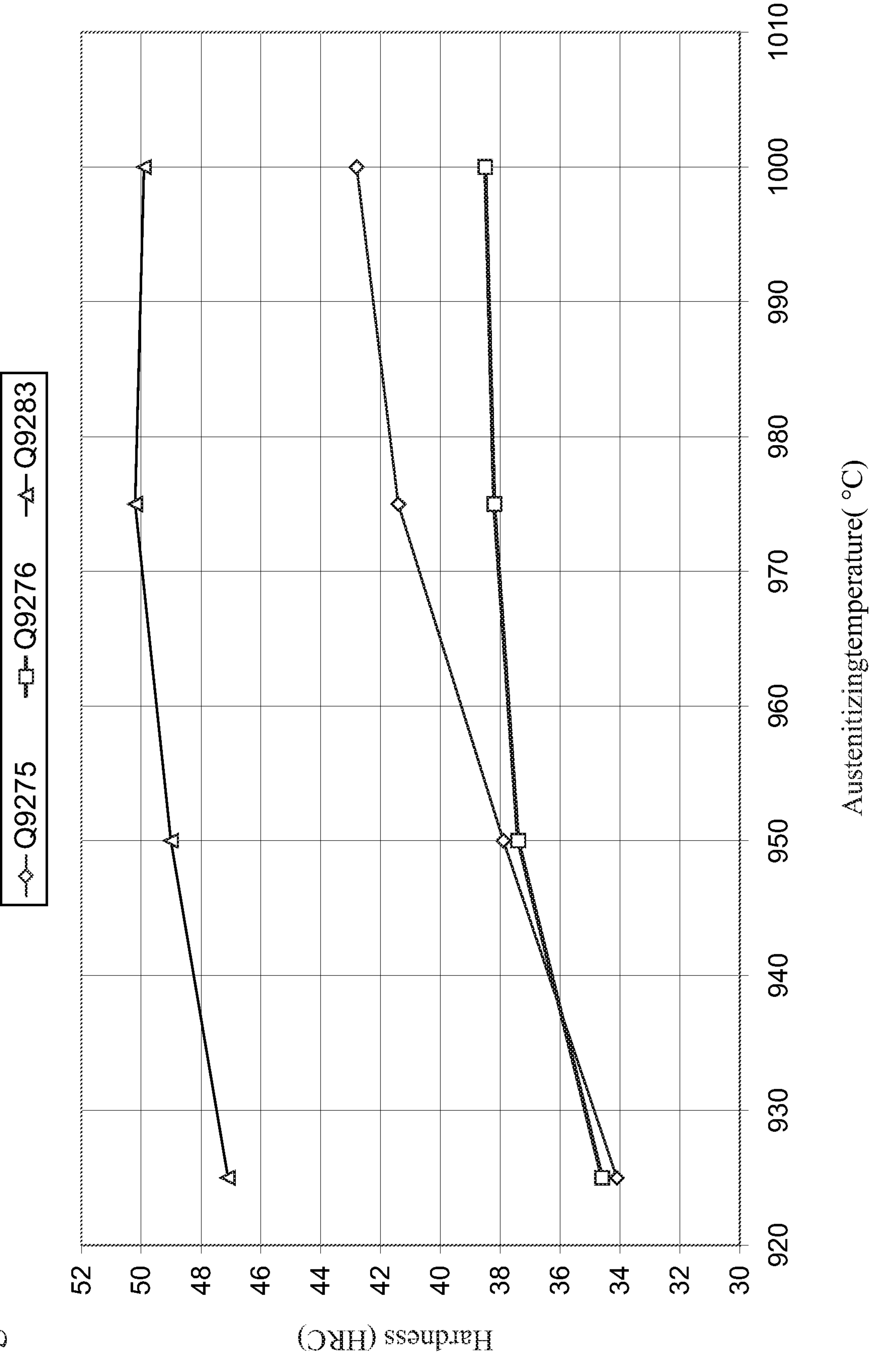

Q9271
Q9272
Q9273
Q9274
Hardness (HRC)
54
52
50
48
46
44
42
40
38
36
34
32
30
920
930
940
950
960
970
980
990
1000
1010
Austenitizingtemperature(°C)

Fig.2C


Q9275
Q9276
Q9283
Hardness (HRC)
52
50
48
46
44
42
40
38
36
34
32
30
Austenitizingtemperature(°C)
920
930
940
950
960
970
980
990
1000
1010

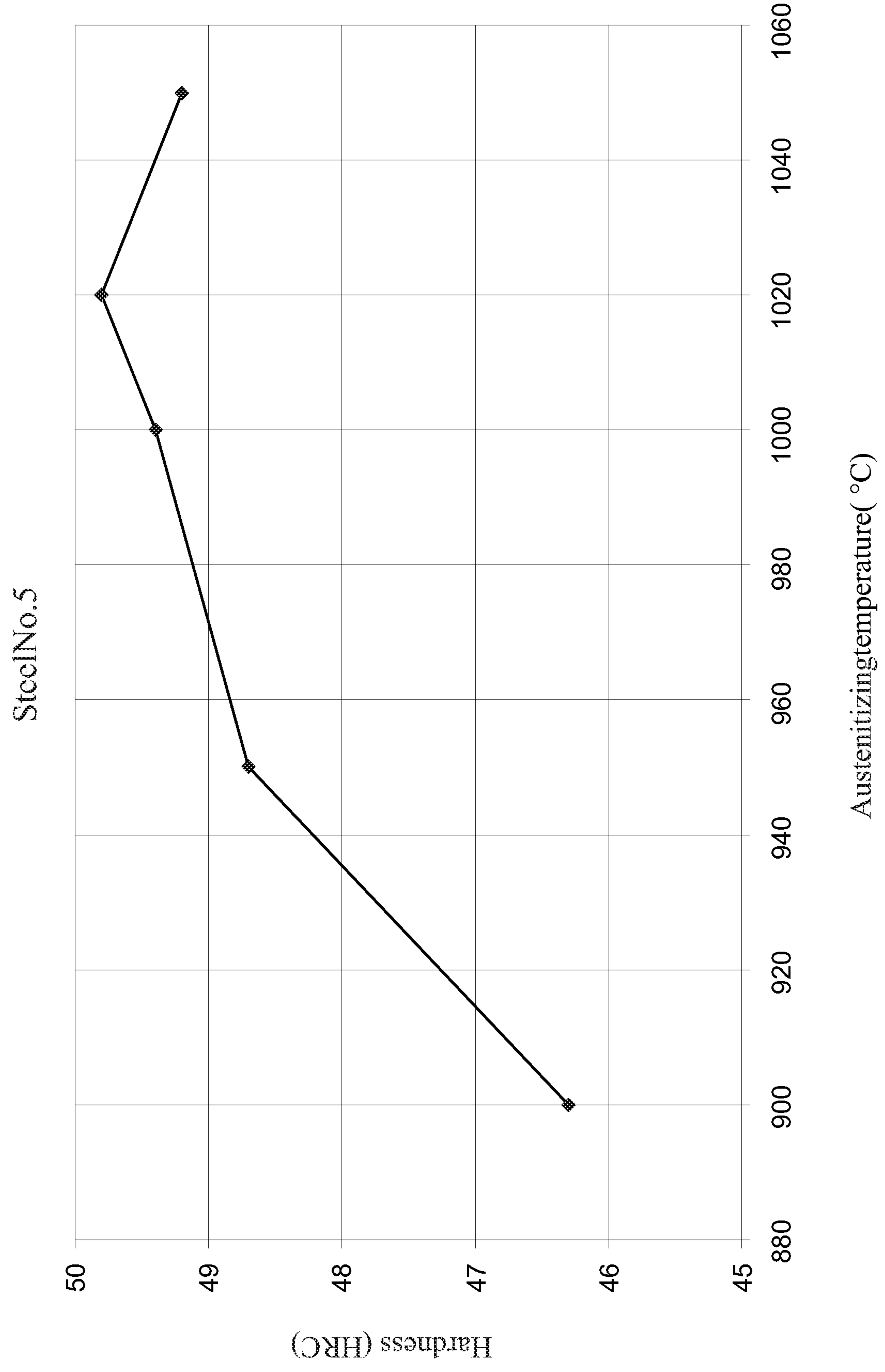

SteelNo.5
Hardness (HRC)
Austenitizingtemperature(°C)
50
49
48
47
46
45
880
900
920
940
960
980
1000
1020
1040
1060

Fig.2D

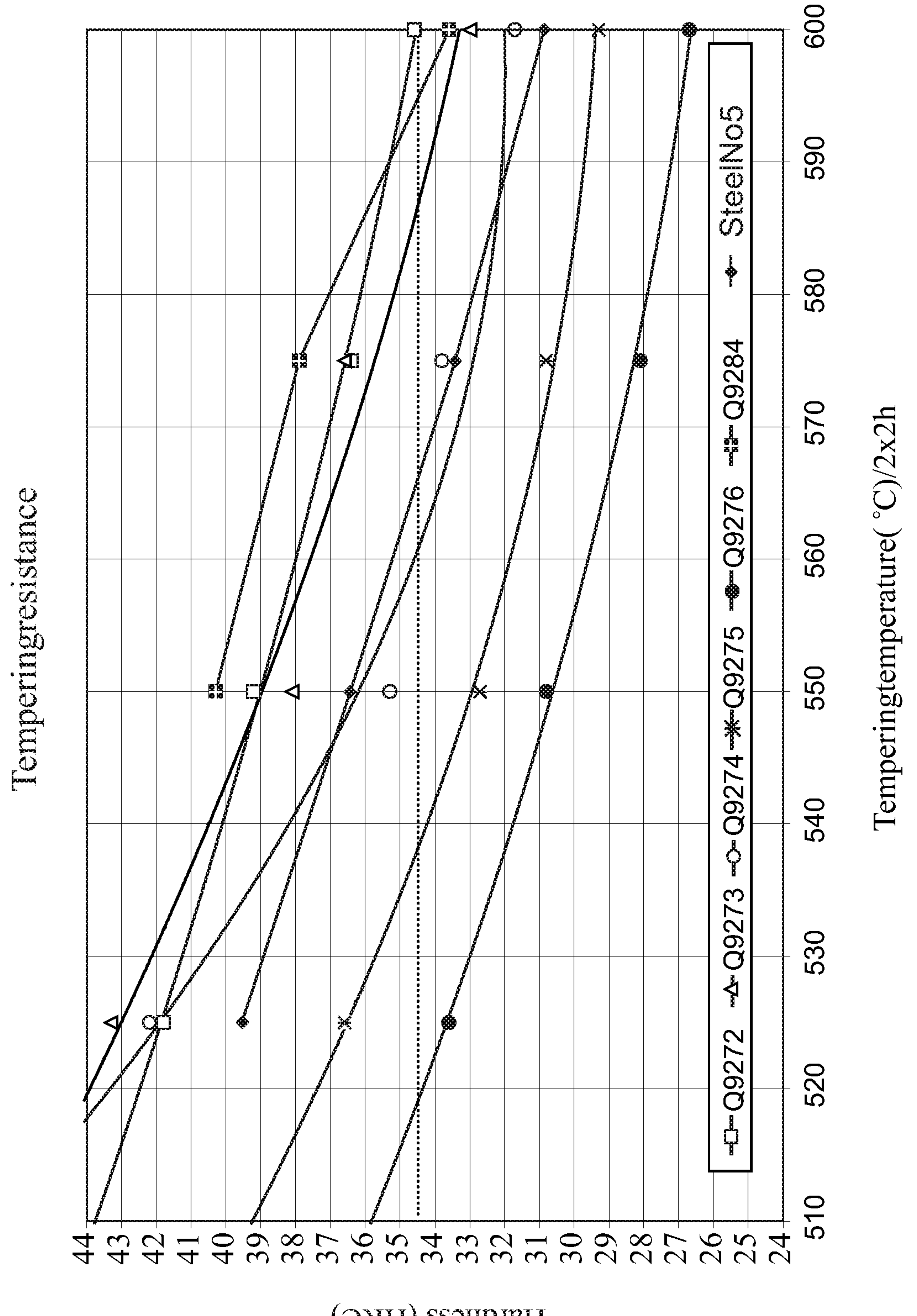

Temperingresistance
Hardness (HRC)
44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24
510 520 530 540 550 560 570 580 590 600
Temperingtemperature(°C)/2x2h
Q9272
Q9273
Q9274
Q9275
Q9276
Q9284
SteelNo5

Fig.3

Hardenability

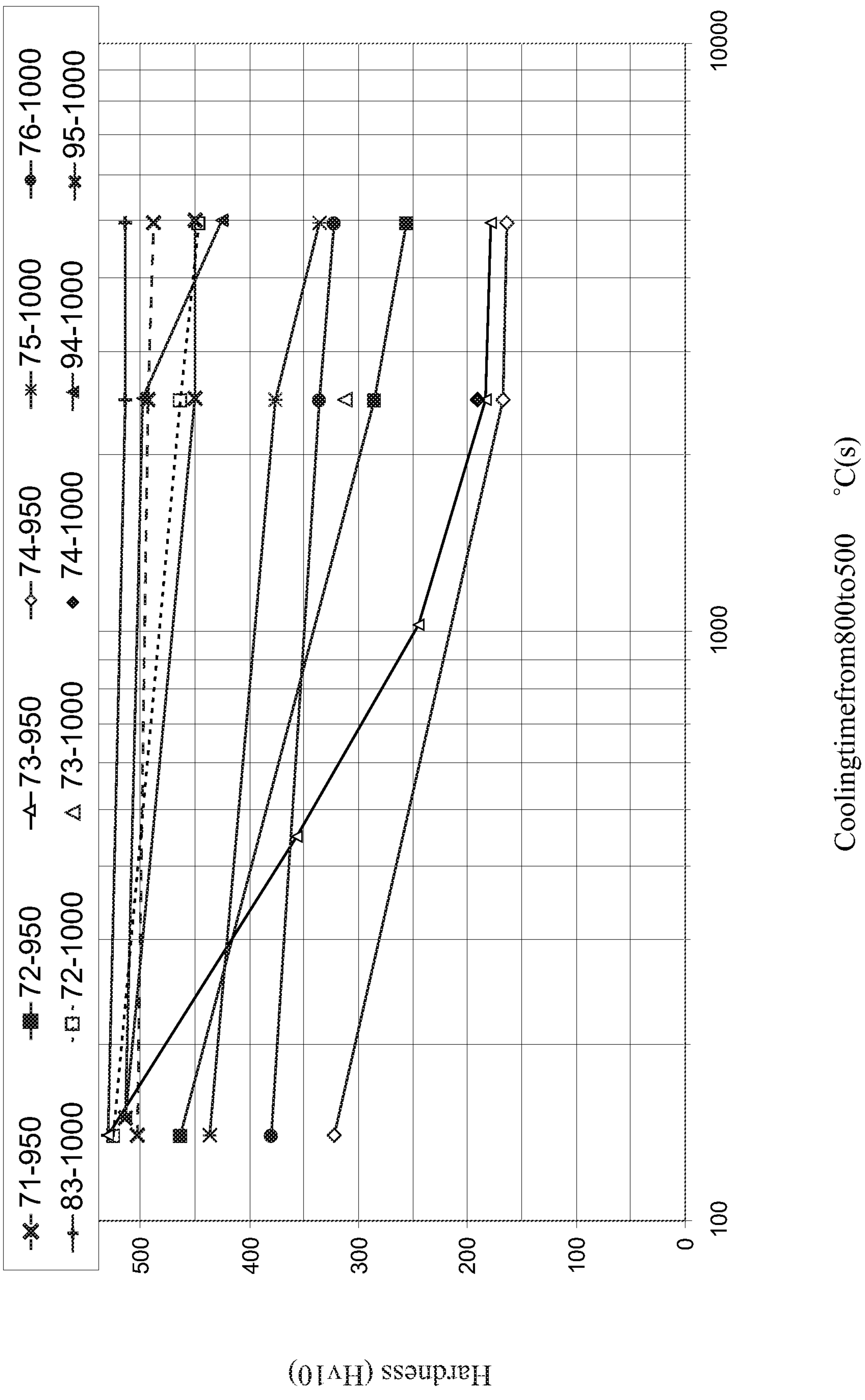


Fig.4A

Hardenability

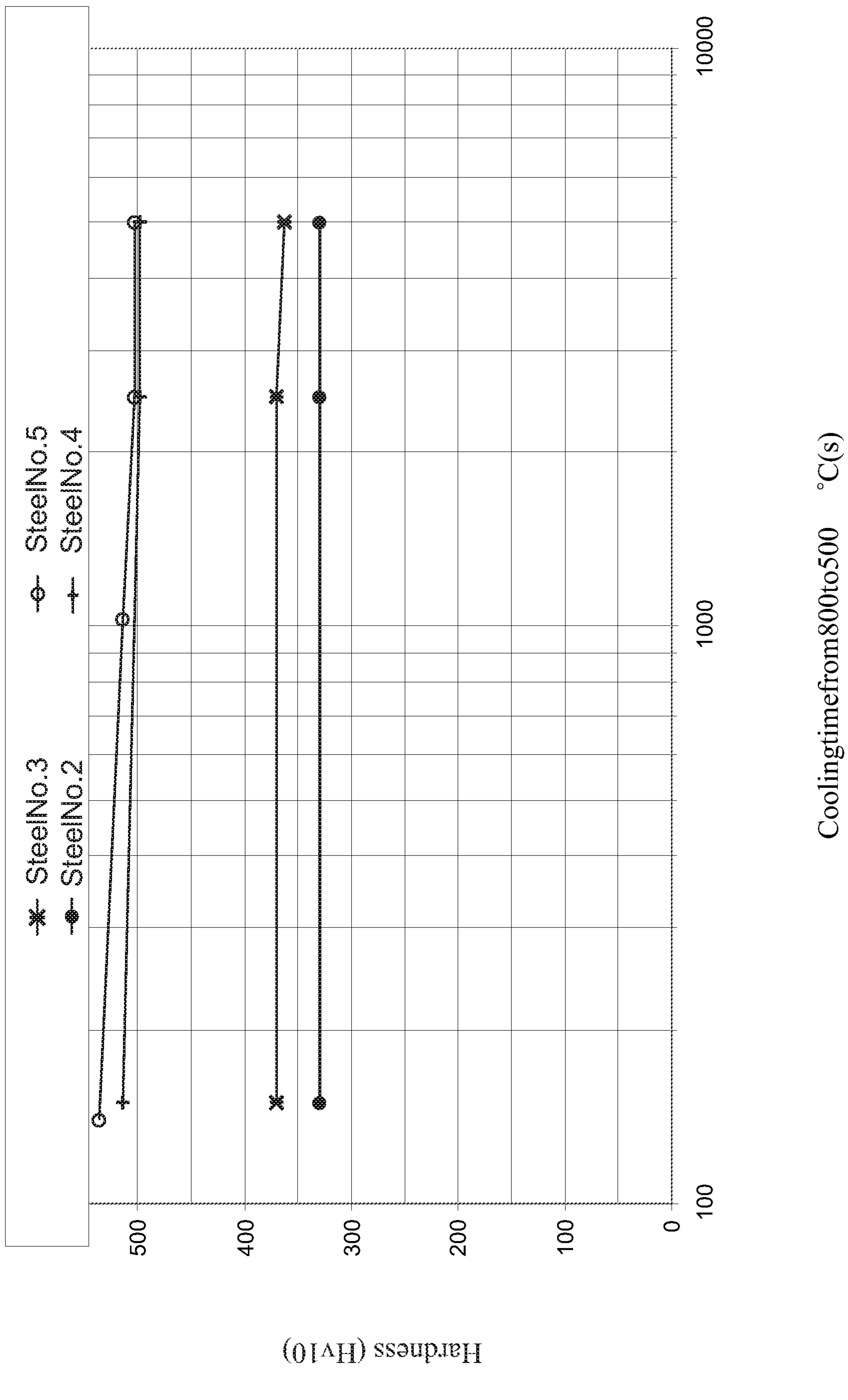


Fig.4B

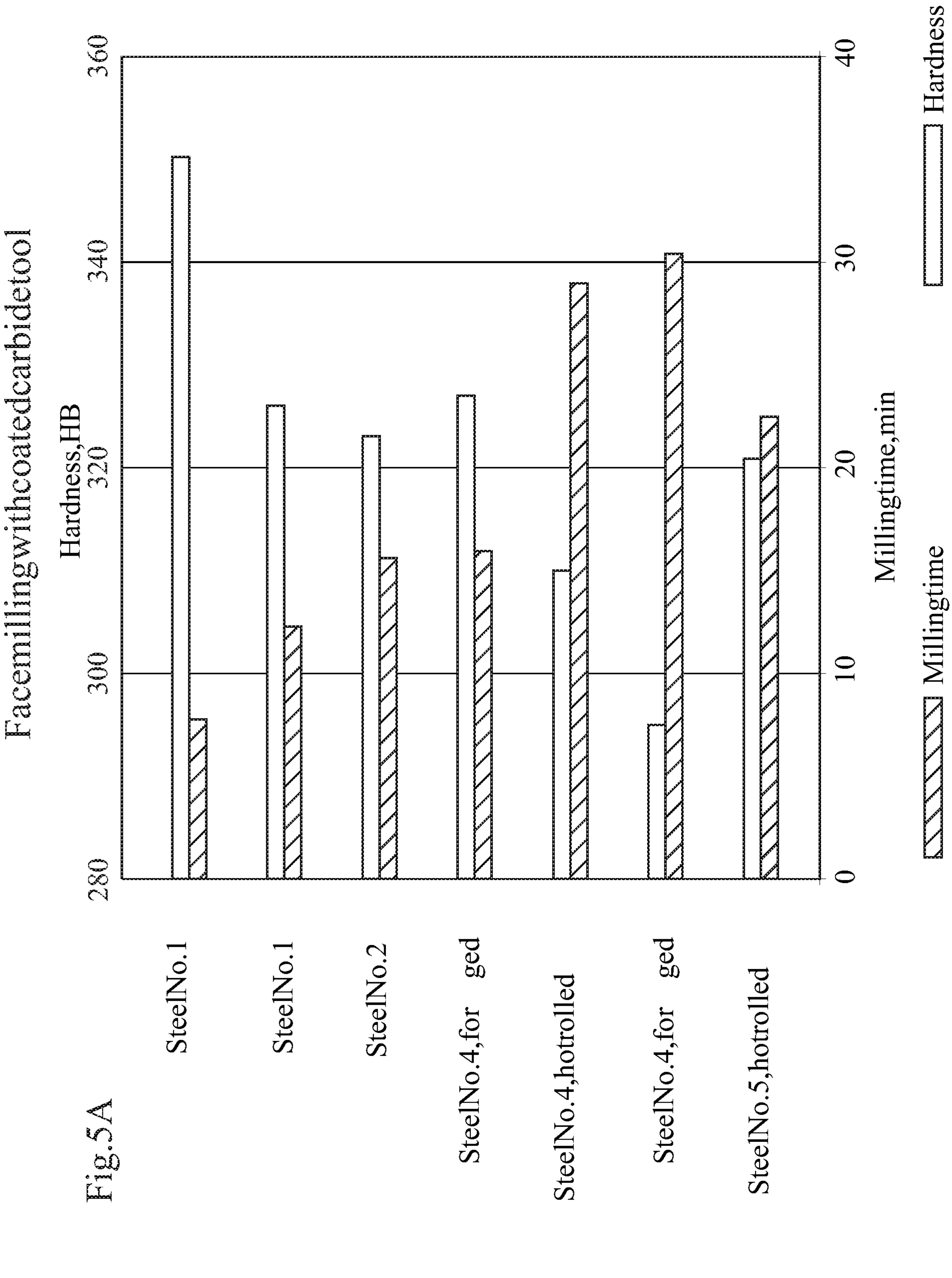
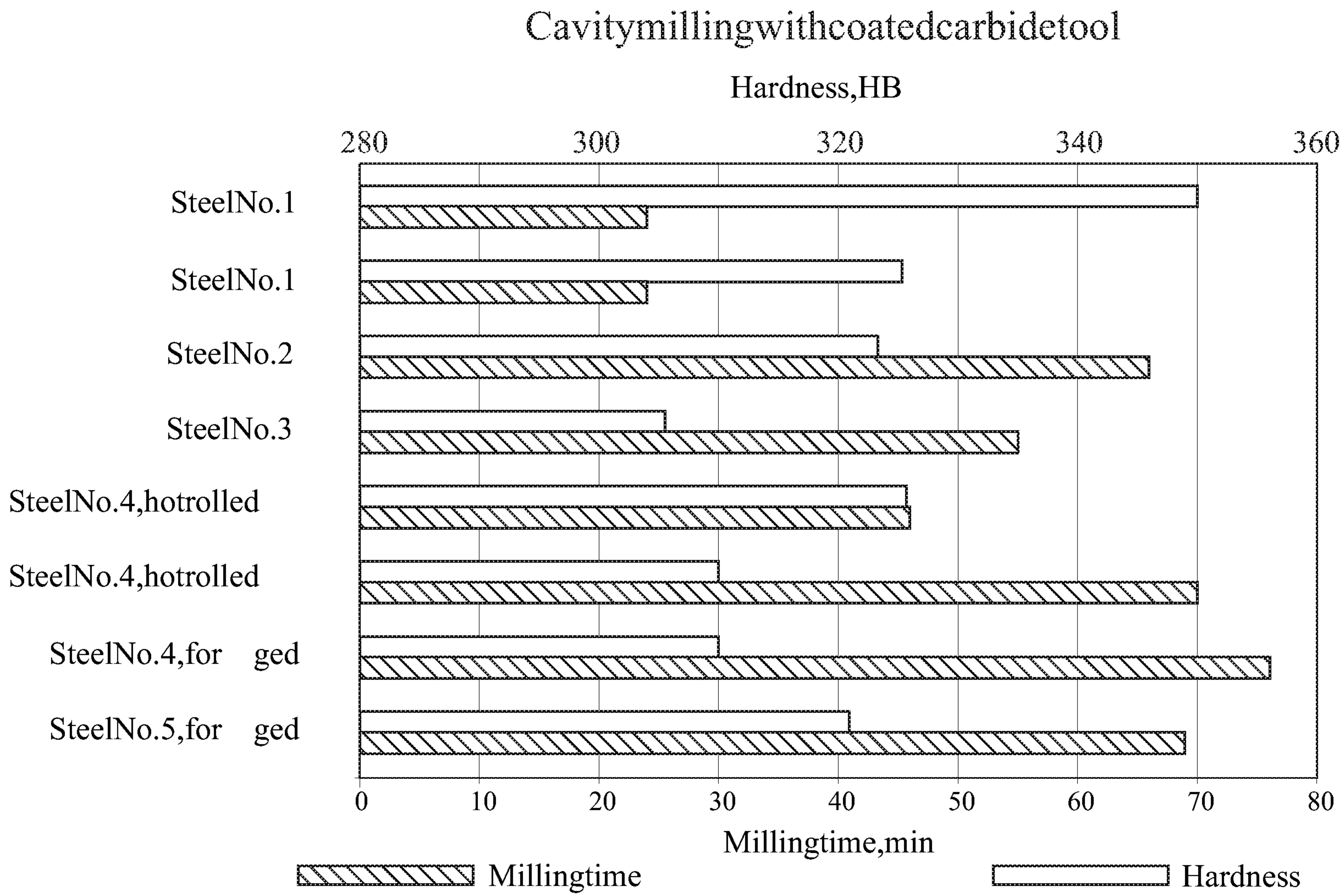

Facemillingwithcoatedcarbidetool
Hardness,HB
280
300
320
340
360
0
10
20
30
40
Millingtime,min
SteelNo.1
SteelNo.1
SteelNo.2
SteelNo.4,for ged
SteelNo.4,hotrolled
SteelNo.4,for ged
SteelNo.5,hotrolled
Millingtime
Hardness

Fig.5A

Fig.5B


Cavitymillingwithcoatedcarbidetool
Hardness,HB
280
300
320
340
360
SteelNo.1
SteelNo.1
SteelNo.2
SteelNo.3
SteelNo.4,hotrolled
SteelNo.4,hotrolled
SteelNo.4,for ged
SteelNo.5,for ged
0
10
20
30
40
50
60
70
80
Millingtime,min
Millingtime
Hardness

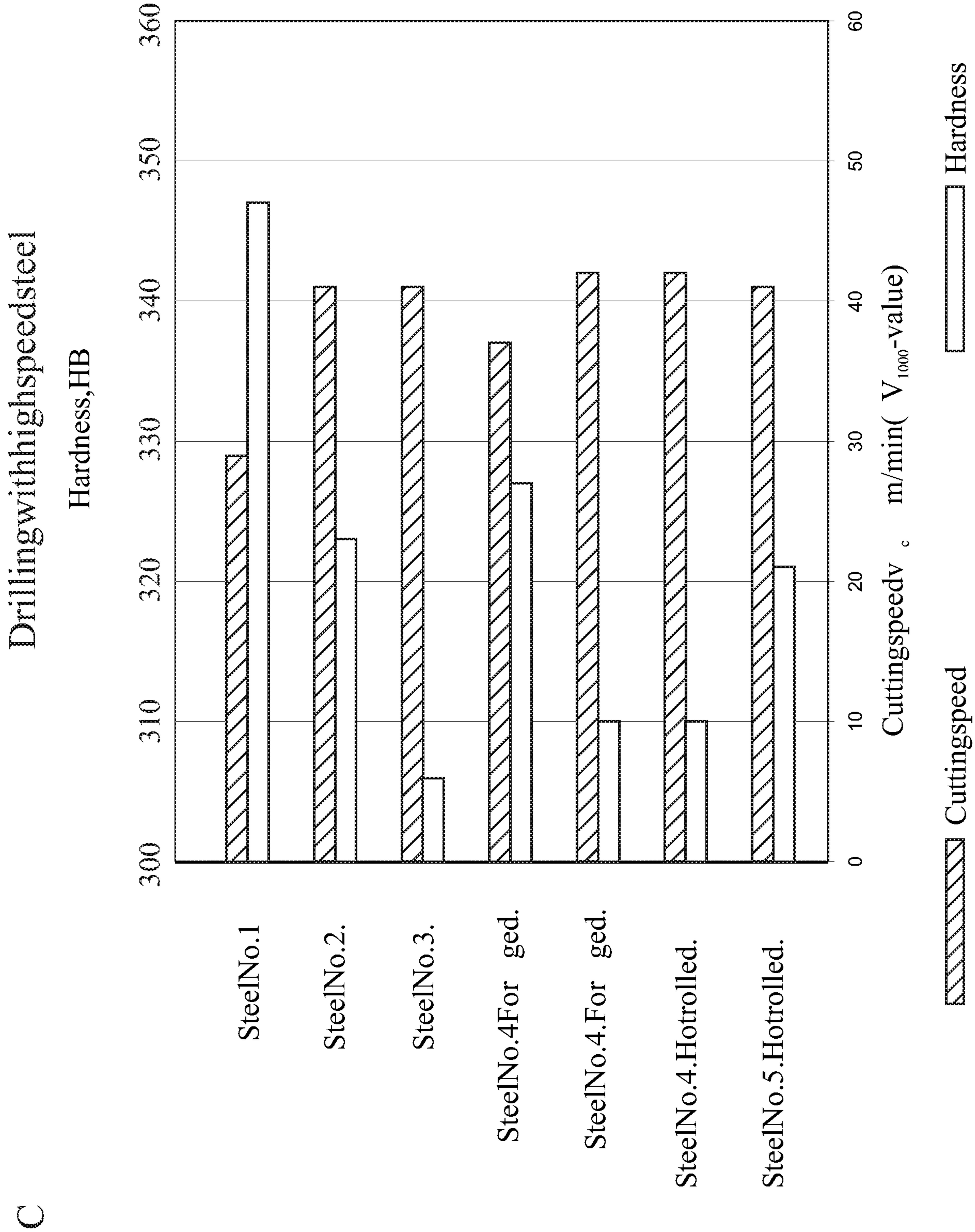

Drillingwithhighspeedsteel
Hardness,HB
300
310
320
330
340
350
360
SteelNo.1
SteelNo.2.
SteelNo.3.
SteelNo.4For ged.
SteelNo.4.For ged.
SteelNo.4.Hotrolled.
SteelNo.5.Hotrolled.
0
10
20
30
40
50
60
Cuttingspeedv c m/min(V1000-value)
Cuttingspeed
Hardness

Fig.5C

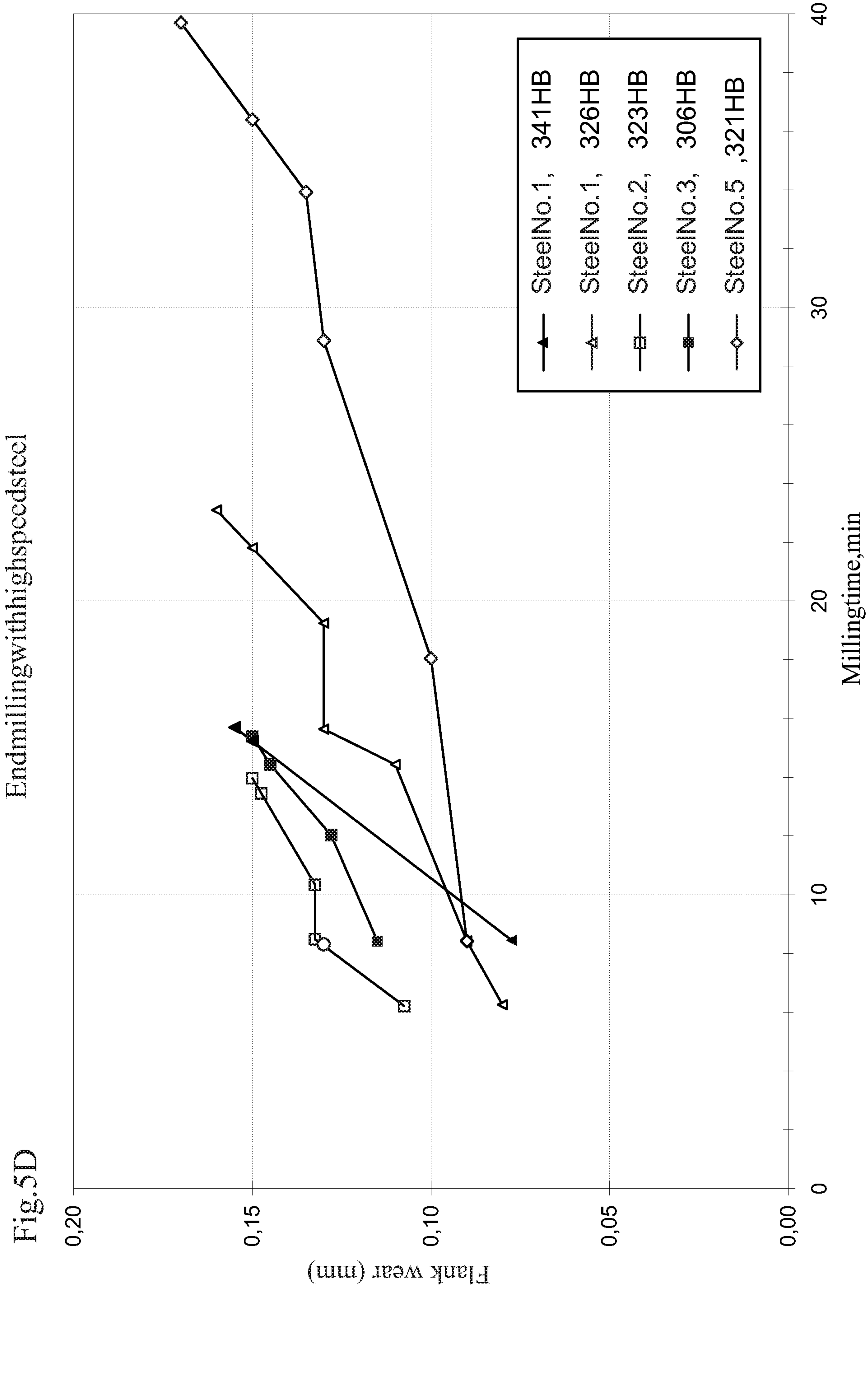
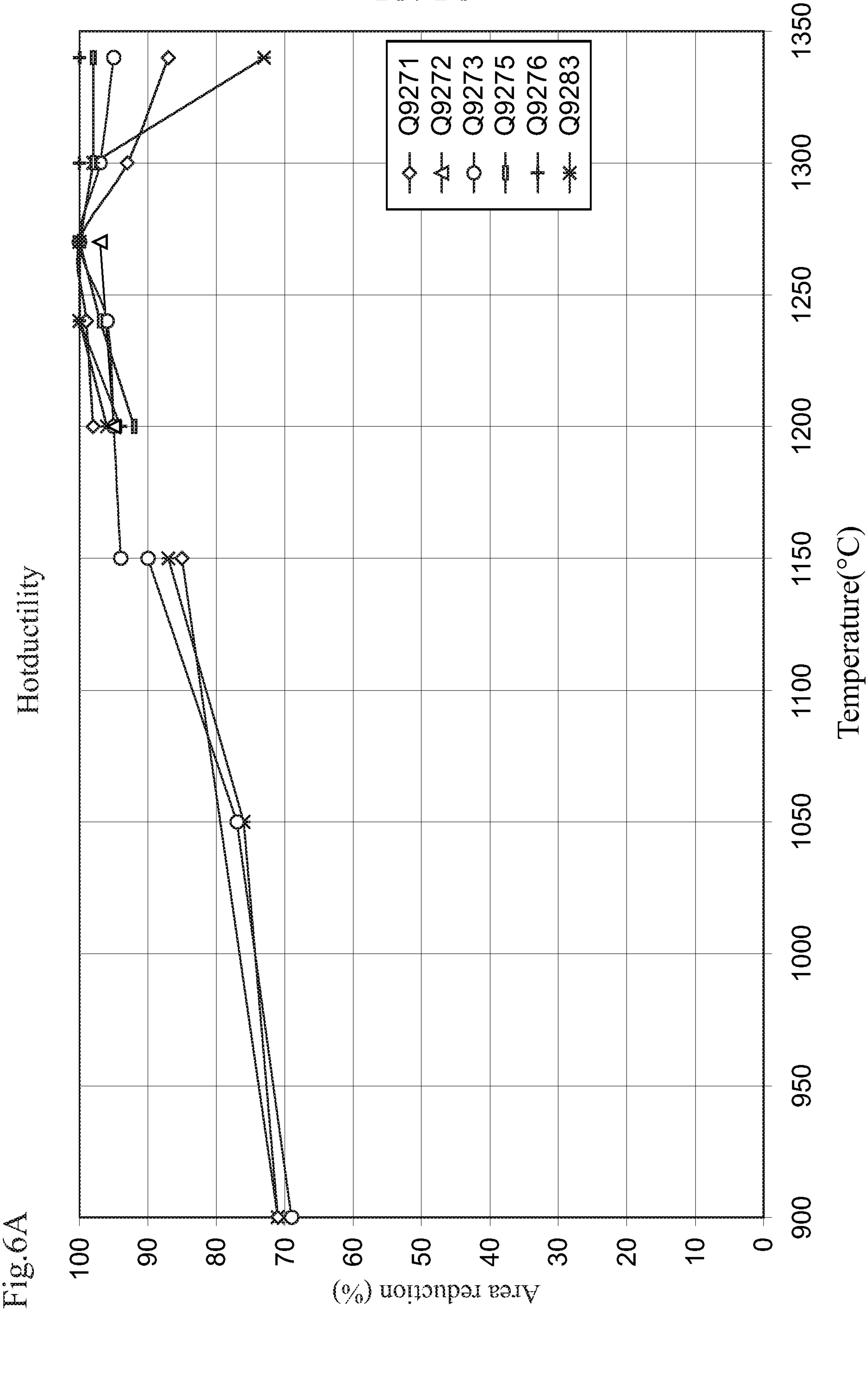

Endmillingwithhighspeedsteel
Flank wear (mm)
0,20
0,15
0,10
0,05
0,00
0
10
20
30
40
Millingtime,min
SteelNo.1, 341HB
SteelNo.1, 326HB
SteelNo.2, 323HB
SteelNo.3, 306HB
SteelNo.5 ,321HB

Fig.5D

Fig.6A


Hotductility
Area reduction (%)
Temperature(°C)
Q9271
Q9272
Q9273
Q9275
Q9276
Q9283
0
10
20
30
40
50
60
70
80
90
100
900
950
1000
1050
1100
1150
1200
1250
1300
1350

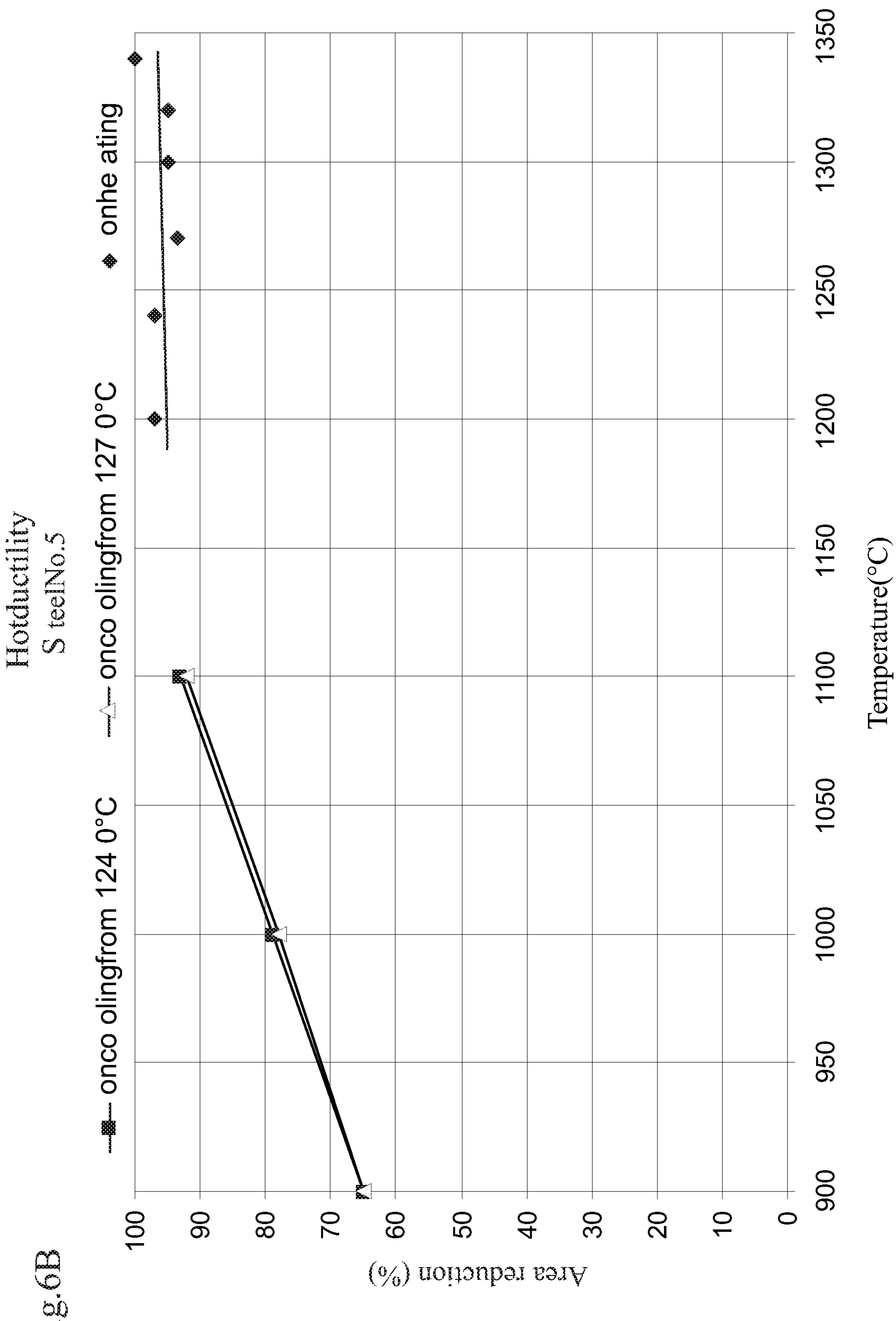

Hotductility
S teelNo.5
onco olingfrom 124 0°C
onco olingfrom 127 0°C
onhe ating
Area reduction (%)
100
90
80
70
60
50
40
30
20
10
0
900
950
1000
1050
1100
1150
1200
1250
1300
1350
Temperature(°C)

Fig.6B

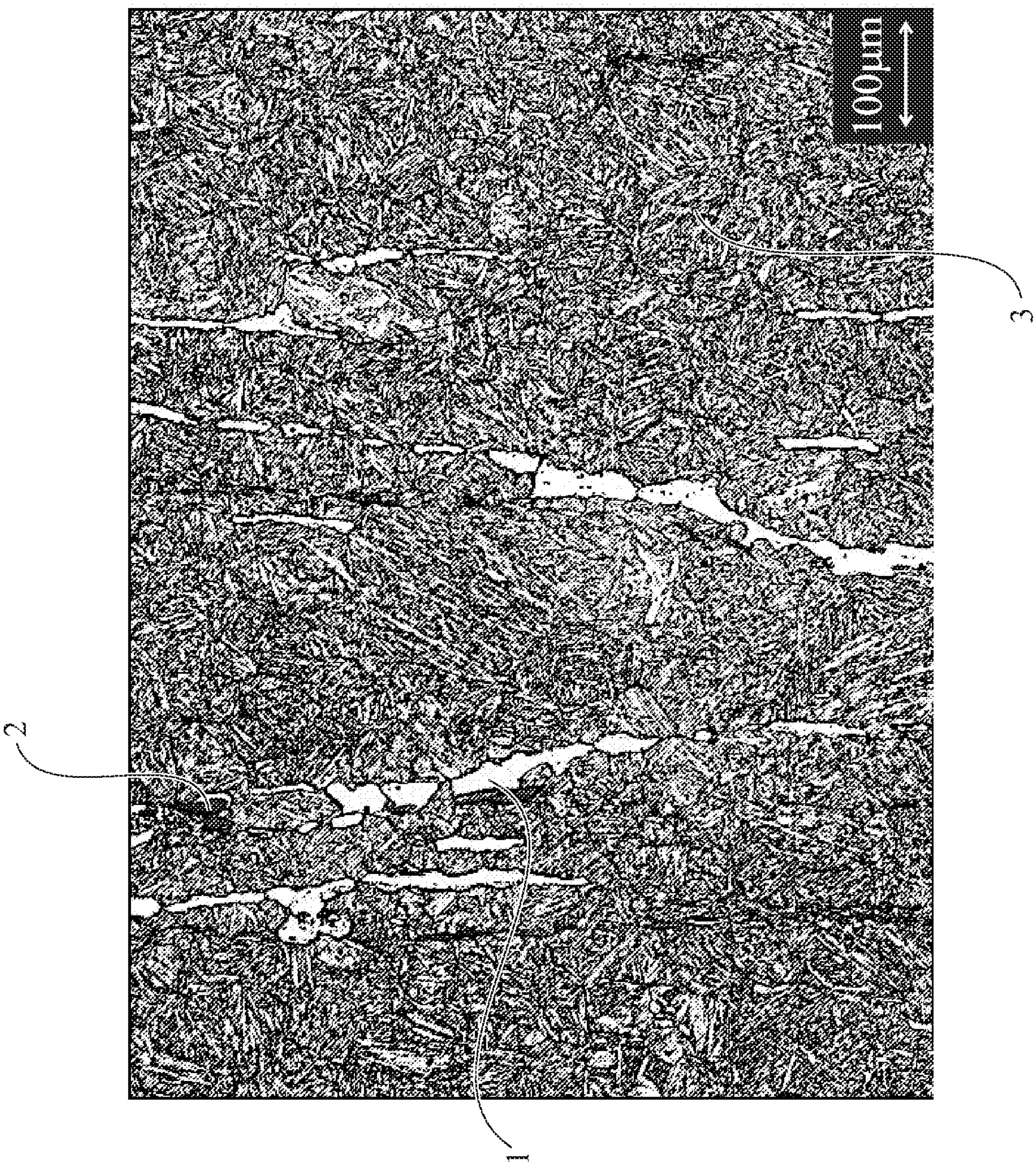
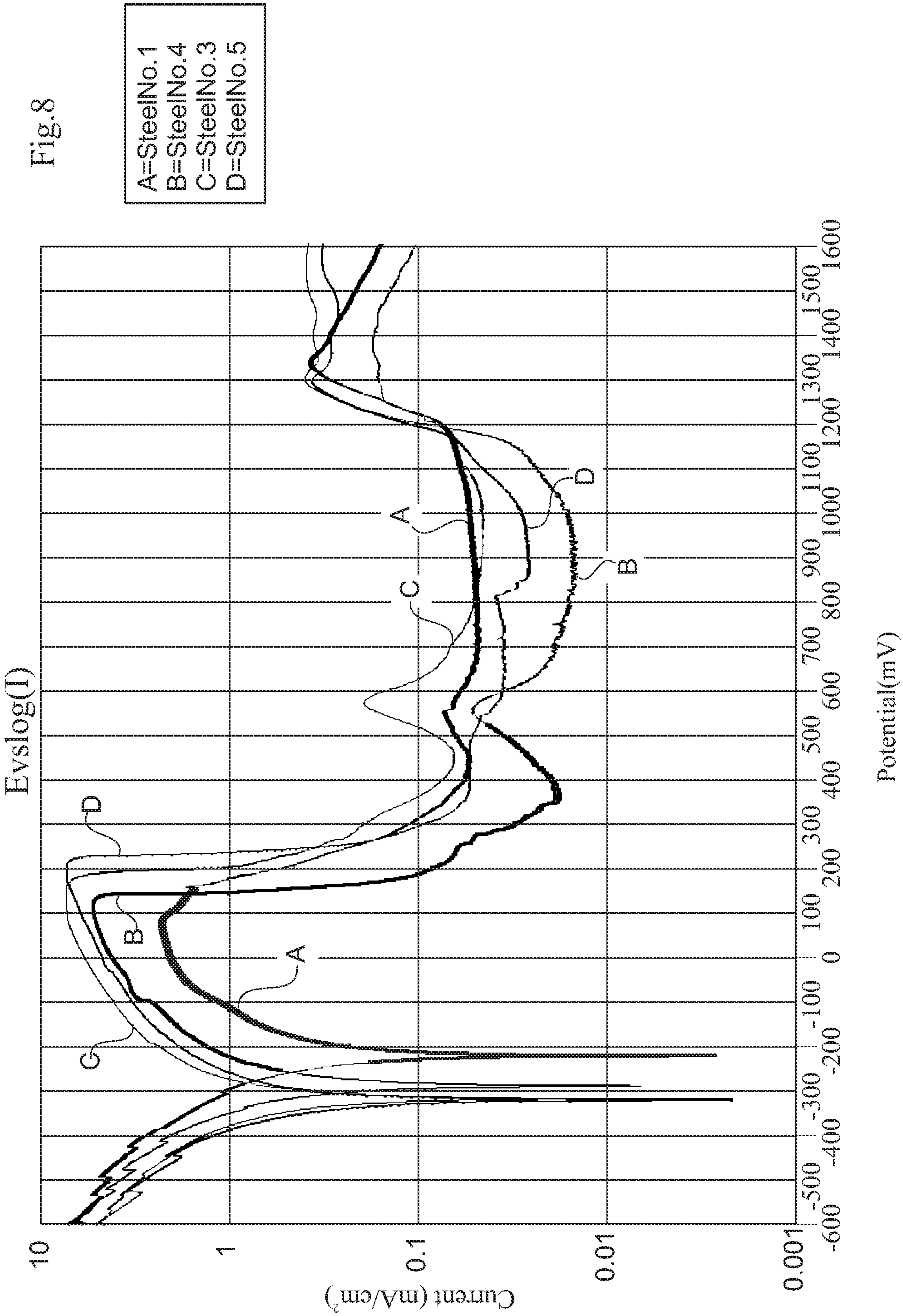
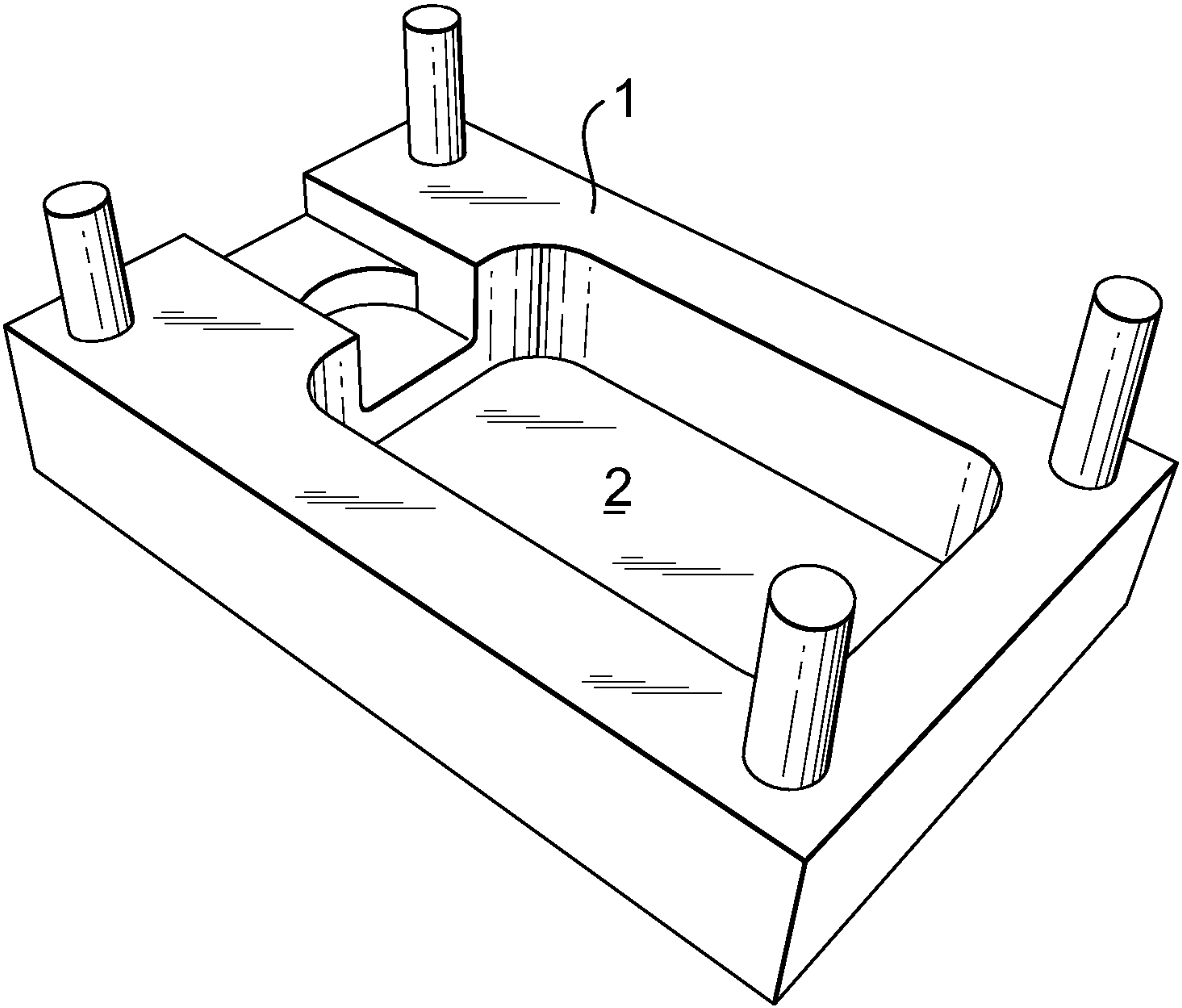


Fig.7

Fig.8


A=SteelNo.1
B=SteelNo.4
C=SteelNo.3
D=SteelNo.5
Evslog(I)
Current (mA/cm²)
Potential(mV)
10
1
0.1
0.01
0.001
-600
-500
-400
-300
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
A
B
C
D


1
2