

HOT-WORKING STEEL

TECHNICAL FIELD

- 5 The invention relates to hot-working steel, i.e. steel intended to be used in the working in hot condition of a working material. Typical examples of the use of the steel are tools for the extrusion pressing of light metals, primarily aluminium. Another form of use is in forging tools. The invention also relates to use of the steel in the manufacturing of hot-working tools and to tools manufactured from the steel.

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BACKGROUND OF THE INVENTION

- There are many requirements on high quality hot-working tools, such as a good resistance to hot wear and a beneficial combination of other properties such as tempering resistance, toughness, hardenability and strength. It is important for optimal
- 15 tool performance that these properties are satisfied. Tools for extrusion pressing of metals such as aluminium are exposed to demanding operating conditions in terms of temperature, pressure and abrasive wear. Extrusion pressing means that material in a plasticized condition is pressed through a restriction/nozzle in which the extruded profile/shape of the extrusion pressed material is formed. Hence, an extrusion pressing
- 20 nozzle must have high strength in combination with good resistance to hot wear as well as good resistance to tempering at high temperatures, since a material such as aluminium is normally extruded at temperatures of about 500-600 °C. A well known and long used hot-working steel is denoted H13 (or alternatively H11) according to AISI and has the following nominal composition in % by weight. 0.30 – 0.40 C, 0.20-
- 25 0.40 Mn, 0.80-1.20 Si, 4.75-5.50 Cr, 1.25-1.75 Mo, 0.80-1.20 V, balance iron and unavoidable impurities, and for H11, in % by weight: 0.30-0.50 V, the remainder the same as for H13. Over the years many different lines of development have been investigated with the purpose of improving certain properties of the conventional steel H13. Examples are EP 632139, US 4,886,640 and US 4,853,181.

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A drawback in common for all steels mentioned above is that they have a relatively high content of expensive alloying materials. It is realised that this is an essential drawback that it for long has been a desire to be able to minimize.

- 35 ACCOUNT OF THE INVENTION

Based on many years of experiments we have now succeeded in minimizing the above mentioned problems by a steel having the following chemical composition in % by weight:

- 0.30-0.50% C
- 5 0-1.5% Si
- 0-1.8% Mn
- 1.5-3.5% Cr
- 0.3-0.9% (Mo + W/2)
- 0.4-0.8% (V + N/2)
- 10 Remainder iron and unavoidable impurities.

Thanks to the invention, a hot-working steel can now be provided that, for most applications, has properties comparable with a traditional H13 steel but having a alloying cost that is almost the half (at the metal prices of today). Based on the fact that
15 different steels of H13 type have been on the market for a long time, it is realised that it must be considered surprising that we have been able to find an alloy that is so efficient in solving the above mentioned problems, especially when considering that the important properties of resistance to hot wear against aluminium and thermal conductivity are improved as compared to a traditional H13 alloy. It is true that
20 hardenability is somewhat impaired, but as most extrusion tools on the market are used for fairly small dimensions, it is estimated that about 70-80% of the existing production can use of this new alloy, resulting in a considerably reduced cost at a functionality that for the rest is maintained.

25 When nothing else is stated the present description always refers to percent by weight in respect of the chemical composition of the steel and percent by volume in respect of the structural components of the steel.

The following is true for individual alloying materials and their mutual relations and for
30 the structure and heat treatment of the steel.

Carbon should be present in an adequate amount to give the steel the desired hardness after heat treatment and to contribute to hardenability. Accordingly, there must be at least 0.3% and for the best result about 0.4% of carbon. Too much carbon has a negative
35 effect on toughness and hence the upper limit should be about 0.45%.

Silicon is present as a residual element from the manufacturing of the steel, at a content of normally at least 0.2%, most often about 1%. Silicon increases the carbon activity in the steel and hence it contributes to give the steel an adequate hardness. It also contributes to an adequate resistance to oxidation and tempering. Contents that are too high may lead to brittleness problems due to solution hardening and hence the maximum content of silicon in the steel is 1.5%, preferably not more than 1.2%.

Manganese, chromium and molybdenum should be present in the steel at an amount high enough to give the steel an adequate hardenability.

Molybdenum has the property that it, besides contributing to hardenability also contributes to a good tempering resistance. Hence, it has been proven that molybdenum is needed at a content of at least 0.3% but not more than 0.8%. Preferably, it is used 0.6% of molybdenum.

Besides hardenability, chromium also contributes to the alloy's oxidation resistance and it should be present at a content of at least 1.5% but not more than 3.0%. The nominal content of chromium is preferably 2.6%.

Manganese should be present at a content of at least 0.7% in order to contribute in giving the steel a desired hardenability at the limited content of molybdenum and chromium that characterises the steel. The steel should not contain more than 1.8% manganese. The nominal content of manganese is preferably 1.4 %.

Vanadium should be present in the steel at a content of at least 0.4% and not more than 0.7%. Vanadium also contributes to give the steel good tempering resistance, good resistance to wear and also contributes to good strength by forming vanadium carbides that contribute to the formation of a relatively fine crystal structure.

Conventional, known production techniques can be used for the manufacturing of the steel.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following description of experiments made, reference will be made to the enclosed drawings, of which

Fig. 1 shows a graph over the desired resistance to hot wear, for gas nitrided samples in a 4 h test, and

Fig. 2 shows the corresponding test results in an 8 h test.

ACCOUNT OF CONDUCTED EXPERIMENTS

- Three alloys have been made in the form of laboratory scale ingots with a weight of 50 kg, by the following process: Forging at 1270°C to the dimension 60 x 60 mm. Soft-annealing at 850°C/2h, cooling by 10°C/h to 600°C and thereafter free cooling in air.

The chemical compositions of the investigated charges are shown in Table 1 below.

- Table 1. Chemical composition (% by weight) of investigated charges, remainder iron and impurities.

Ingot No.	C	Si	Mn	P	S	Cr	Mo	V	Al	N	O ppm
2	0.37	1.06	0.41	0.019	0.001	5.16	1.47	0.82	0.001	0.04	40
6	0.42	0.93	1.25	0.004	0.007	2.53	0.60	0.57	0.001	0.047	50
7	0.38	0.59	1.34	0.005	0.006	2.29	0.55	0.52	0.53	0.023	32

The alloys are heat treated according to Table 2 below.

- Table 2. Austenitizing and tempering temperatures, and expected hardness of the various alloys.

Alloy	T _A (°C) 30 min	T _{Temp} (°C) 2x2h	HRC
2	1020	580	48
6, 7	1020	560	48

- Plate samples having the dimension 5 x 10 x 30 mm are produced of each species according to Table 2. One surface of the sample, a side of 5 x 30 mm, is polished fine with an R_A of about 0.10-0.15 µm.

- The different samples were investigated to compare hot wear against aluminium. Fig. 1 shows the volume worn off after about 4 h for gas nitrided samples. The graph shows that both samples produced according to the invention, i.e. samples 6 and 7, have improved resistance to wear as compared with the reference steels (sample no. 2).

Fig. 2 shows the result from a corresponding 8 h test, showing that an improved resistance to wear could be confirmed for the invention also in such an experiment. In

one case (sample no. 6), the improvement is more than 50% in respect of resistance to wear, as compared with a traditional H13 steel (sample 2).

It is hence evident, when comparing a steel according to the invention with a classic H13 steel (sample 2) having the composition in % by weight: 0.30 – 0.40 C, 0.20-0.40 Mn, 0.80-1.20 Si, 4.75-5.50 Cr, 1.25-1.75 Mo, 0.80-1.20 V, balance iron and unavoidable impurities, that the steel according to the invention, having the composition in % by weight: 0.4 C, 0.5-1.0 Si, 1.2-1.4 Mn, 2.2-2.5 Cr, 0.5-0.6 Mo, 0.5-0.6 V, is much improved in respect of the very important property of wear resistance, despite the lower content of alloying materials and lower cost. Considering the conventional understanding in the present technical field, these results are sensational since the prevalent teaching is that a lowering of the content of chromium and/or molybdenum and/or vanadium should result in an impaired nitrification potential. According to the prevalent understanding, the changes made in a steel according to the invention, as compared with a traditional H13 steel, ought accordingly result in a relatively seen impaired nitrification potential and hence an impaired resistance to wear. Obviously, some type of mechanisms arise in a steel according to the invention, resulting in an excellent nitrification potential and hence the ability to achieve a good resistance to wear, despite the decreased contents of chromium, molybdenum and vanadium.

It is realised that the invention is not limited to the preferred, narrow ranges mentioned above, but that many variants are accommodated within the scope of the invention as defined in claim 1, while still retaining the required good properties. Aspects that are specifically preferred according to the invention are set out in the dependent claims.

It is clear from the table below (Table 3) that the steel according to the invention fulfils the properties desired for an H13 steel, which table gives a weighted comparison of important properties, wherein 10 is the highest rating corresponding to the best test result (for the comparison between a traditional H13 steel and the invention) and the rating of the comparing sample being weighted in relation to the best rating.

Table 3.

	Invention	H13
Nitrification potential	The same	The same
Alloying cost	10	5
Yield %	The same	The same
Processability	The same	The same

Thermal fatigue strength	7	10
Ductility (20°C, 44 HRC)	The same	The same
Charpy-V (20°C, 48 HRC)	The same	The same
Hardenability	6	10
Resistance to wear against aluminium (550°C)	10	7
Tempering resistance	8	10
Strength (550°C)	9	10
Thermal conductivity	10	9

It is clear from the table above that the ratings of the invention are very good in respect of properties important for an H13 steel, and that it is possible even to achieve improved ratings in respect of the very important properties resistance to wear against aluminium and thermal conductivity, although the alloying cost is lowered by almost 50%.

CLAIMS

1. A hot-working steel, characterised in that it has the following chemical composition in % by weight:
5 0.30-0.50% C
0-1.5% Si
0-1.8% Mn
1.5-3.5% Cr
0.3-0.9% (Mo + W/2)
10 0.4-0.8% (V + N/2)
Remainder iron and unavoidable impurities.
2. A steel according to claim 1, characterised in that the content of (Mo + Cr), in % by weight, is less than 3,5%.
- 15 3. A steel according to claim 1, characterised in that the content of Mn, in % by weight, is more than 1%.
4. A steel according to any one of the preceding claims, characterised in that
20 the content of C, in % by weight, is 0.38-0.46, preferably 0.40-0.44% C.
5. A steel according to any one of the preceding claims, characterised in that the content of Si, in % by weight, is 0.3-1.35%, preferably 0.5-1.2%.
- 25 6. A steel according to any one of the preceding claims, characterised in that the content of Mn, in % by weight, is 0.3-1.5%, preferably 0.5-1.35%.
7. A steel according to any one of the preceding claims, characterised in that the content of Cr, in % by weight, is 0.7-3.0%, preferably 2.2-2.8%.
- 30 8. A steel according to any one of the preceding claims, characterised in that the content of Mo, in % by weight, is 0.45-0.8%, preferably 0.5-0.7%.
9. A steel according to any one of the preceding claims, characterised in that
35 the content of V, in % by weight, is 0.45-0.7.

10. A steel according to any one of the preceding claims, characterised in that the content of Cr in relation to the content of Mo, in % by weight, is such that $\%Cr/\%Mo > 3$.
- 5 11. A steel according to any one of the preceding claims, characterised in that the content of Mo as well as the content of V are both less than 0.7 % by weight.
12. A steel according to claim 11, characterised in that the content of V is 0.5-0.6 % by weight.
- 10 13. A steel according to claim 1, characterised in that it contains not more than 0.05 % by weight of Al.
14. A steel according to claim 1, characterised in that the content of Al, in % by weight, is 0.3-1.0%, preferably about 0.7%.
- 15 15. A hot-working steel, characterised in that it has a chemical composition according to any one of the preceding claims.
- 20 16. A hot-working steel according to claim 10 or 11, characterised in that it has a thermal conductivity of more than 26 W/m °C at 200°C.
17. Use of the steel according to any one of claims 1-12 for the production of a tool for extrusion pressing, preferably extrusion pressing of aluminium.