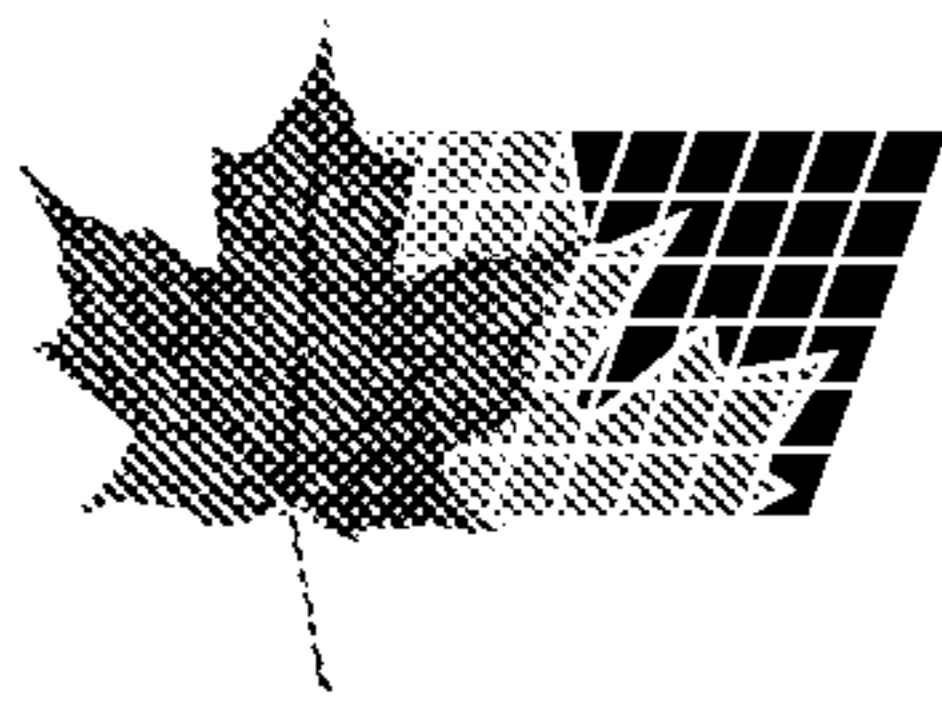




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(54) **MOULAGES DE CULASSES ET DE BLOCS-CYLINDRES**

(54) **CYLINDER HEAD AND MOTOR BLOCK CASTINGS**

(57) The invention relates to a cylinder head and motor block casting made of Si 6.80 - 7.20, Fe 0.35 - 0.45, Cu 0.30 - 0.40, Mn 0.25 - 0.30, Mg 0.35 - 0.45, Ni 0.45 - 0.55 Zn 0.10 - 0.15, Ti 0.11 - 0.15, remainder aluminium and phases of the types aluminium-nickel, aluminium-copper, aluminium-manganese, aluminium-iron as well as mixed phases. For manufacturing an aluminium alloy is filled into a casting mould at a temperature of 720° to 740°C, then the aluminium alloy is subjected to cooling at a cooling rate of 0.1 to 10 K s⁻¹, after the cooling to room temperature a thermal treatment is carried out under the following conditions: solution heat treatment at 530°C for 5 hours, a chilling in water at 80°C and an artificial ageing at a temperature of 160 to 200°C for 6 hours.

Abstract of the Disclosure

The invention relates to a cylinder head and motor block casting made of Si 6.80 - 7.20, Fe 0.35 - 0.45, Cu 0.30 - 0.40, Mn 0.25 - 0.30, Mg 0.35 - 0.45, Ni 0.45 - 0.55 Zn 0.10 - 0.15, Ti 0.11 - 0.15, remainder aluminium and phases of the types aluminium-nickel, aluminium-copper, aluminium-manganese, aluminium-iron as well as mixed phases. For manufacturing an aluminium alloy is filled into a casting mould at a temperature of 720° to 740°C, then the aluminium alloy is subjected to cooling at a cooling rate of 0.1 to 10 K s⁻¹, after the cooling to room temperature a thermal treatment is carried out under the following conditions: solution heat treatment at 530°C for 5 hours, a chilling in water at 80°C and an artificial ageing at a temperature of 160 to 200°C for 6 hours.

Cylinder Head and Motor Block castings

Specification

The invention relates to a cylinder head and motor block casting, consisting of an aluminium alloy having the following composition: Si 6.80 - 7.20, Fe 0.35 - 0.45, Cu 0.30 - 0.40, Mn 0.25 - 0.30, Mg 0.35 - 0.45, Ni 0.45 - 0.55 Zn 0.10 - 0.15, Ti 0.11 - 0.15 with the remainder being aluminium as well as unavoidable impurities with a maximum content of 0.05 each, but not more than a maximum of 0.15 impurities in all.

Background

The properties of aluminium depend on quite a number of factors whereby added or accidentally present admixtures and impurities of other elements play an important part.

The main alloying elements are copper (Cu), silicon (Si), magnesium (Mg), zinc (Zn) and manganese (Mn).

It often happens that the following impurities or additions are contained in small quantities: iron (Fe), chromium (Cr) and titanium (Ti). The following additions are used for special alloys: nickel (Ni), cobalt (Co), silver (Ag), lithium (Li), vanadium (V), zirconium (Zr), tin (Sn), lead (Pb), cadmium (Cd) and bismuth (Bi).

All alloy constituents are completely solvable in liquid aluminium at a high enough temperature. The solubility in the solid state with formation of solid solutions is limited for all elements; there is no alloy system comprising aluminium which shows a uninterrupted solid solution sequence. The unsolved parts form their own phases, so-called heterogeneous constituents, in the alloy microstructure. They are often hard and brittle crystals made up of one element alone (e.g. Si, Zn, Sn, Pb, Cd, Bi) or consisting of intermetallic compounds comprising aluminium (such as Al_2Cu , Al_8Mg_5 , Al_6Mn , Al_3Fe , Al_7Cr , Al_3Ni , AlLi). Alloys having

two or more constituents contain in addition to these inter-metallic compounds, yet other intermetallic compounds consisting of the additions (e.g. Mg_2Si , MgZn_2), ternary phases (e.g. $\text{Al}_8\text{Fe}_2\text{Si}$, $\text{Al}_2\text{Mg}_3\text{Zn}_3$, Al_2CuMg) and phases comprising even more constituents. The formation of solid solutions and the formation of the heterogeneous microstructure constituents (their amount, size, form and distribution) determine the physical, chemical and technological properties of an alloy. Due to the fact that the diffusion rate decreases with temperature it is possible, after a rapid cooling from higher temperatures, that Al-solid solutions may contain higher levels of solved elements than would be possible in equilibrium at room temperature. In such oversaturated solid solutions precipitation processes may occur at room temperature or at moderately raised temperatures (partly with formation of metastable phases), these may be of great influence on the properties. Elements which diffuse slowly such as Mn can be oversaturated far beyond the maximum equilibrium solubility by rapid solidification from the melt. This oversaturation may be remedied by annealing at high temperatures. The additions are then precipitated in a finely dispersed manner. Often this annealing process (full annealing) is used for compensating microsegregation.

Below some important binary and ternary systems are described with short explanations:

Aluminium-copper

In the range of 0 to approximately 53% Cu there is a simple eutectic sub-system with a eutectic at 33.2% Cu and 547°C. The maximum solubility at the eutectic temperature in the alpha solid solution is 5.7%. The solubility decreases with falling temperature and is only 0.45% at 300°C. Unsolved copper is present in the form of Al_2Cu in the state of equilibrium. Metastable transition phases may be formed at medium temperatures by precipitation from the oversaturated solid solution.

Aluminium-silicon

This system is purely eutectic having a eutectic at 12.5% Si and 577°C. At this temperature 1.65% Si are solvable in the alpha solid solution. At 300°C only 0.07% are solvable. The crystallisation of eutectic silicon may be influenced by small amounts of additions (e.g. of sodium or strontium). In this case an overcooling and shift of concentration of the eutectic point occur in dependence on the solidification rate.

Aluminium-magnesium

The subarea between 0 and approx. 36% Mg is eutectic. The eutectic is at approximately 34% Mg and 450°C. At this temperature the (maximum) solubility is 17.4% Mg. At 300°C 6.6 % and at 100°C about 2.0% Mg are solvable in the alpha solid solution. In most cases unsolved Mg is present in the microstructure in the form of the β -phase (Al_8Mg_5).

Aluminium-zinc

The alloys form a eutectic system having a high-level zinc eutectic at 94.5% Zn and 382°C. In the area high in aluminium, which is of interest here, 31.6% Zn are solvable at 275°C in the solid solution. The solubility is very much dependent on the temperature and falls to 14.5% at 200°C and to 3.0% at 100°C.

The systems of aluminium-manganese, aluminium-iron and aluminium-nickel show a eutectic at a low concentration. The melting point is only very slightly lowered. The solubility in the solid state is low except that of manganese.

From the journal "AFS Transactions", Volume 61, 1998, pages 225 to 231, it has been known to optimize aluminium-silicon cast alloys for cylinder heads by adding copper to them. In this case the thermal strength of an AlSi_7Mg -alloy, to which 0.5 to 1% copper had been added, increased significantly whereby simultaneously the creep resistance also improved. The improvement of the mechanical properties, however, is accompanied by a deterioration of ductility and a reduced corrosion resistance.

After having manufactured the cylinder head and motor block castings in a casting process it is often necessary to carry out machining operations on them. In certain alloys problems occur as a result of too little hardness because the surfaces of the castings become very soft so that fine scoring or smudging may occur.

Furthermore, such alloys must have a high thermal conductivity so that the castings are suitable for use in motors. The piston alloys with 12% Si which have been examined by way of comparison do not meet the requirements, nor does the normally used Al-Si9Cu3.

Summary of the Invention

Therefore, an object of the present invention is to provide an alloy suitable for use in cylinder head and motor block castings, having a high thermal conductivity and an appropriate crystalline structure, high thermal strength, good creep resistance as well as sufficient ductility and, at the same time, having low vulnerability to corrosion and being easily machinable.

According to the present invention this object is accomplished by the features in the patent claims.

The research of the inventors has shown that cylinder head and motor block castings consisting of an aluminium alloy comprising the following composition:

Si	6.80 - 7.20
Fe	0.35 - 0.45
Cu	0.30 - 0.40
Mn	0.25 - 0.30
Mg	0.35 - 0.45
Ni	0.45 - 0.55
Zn	0.10 - 0.15
Ti	0.11 - 0.15

remainder aluminium as well as unavoidable impurities with a maximum content of 0.05 each, but not more than a maximum of 0.15 impurities in all, exhibits an especially high creep resistance and thermal strength, if phases in the amounts of 1 to 3 vol.% of the aluminium-nickel type, aluminium copper type, aluminium-manganese type, aluminium-iron type and mixed phases of the aforementioned types are contained and if, in particular, a ratio of Ni : Mg : Cu = 5 : 4 : 3.5 is observed. The thermal conductivity and ductility of a cylinder head and motor block casting are improved by a crystalline structure consisting of an alpha aluminium matrix structure having 40 to 55 vol.% and by observing a Mn/Fe-ratio of at least 0.781. If the aluminium alloy elements are contained in the following ratios

- Si : Fe : Cu = 7 : 0.4 : 0.35
- Ni : Mg : Cu = 5 : 4 : 3.5

the cylinder head and motor block casting according to the present invention shows very good corrosion properties. It was found that cylinder head and motor block castings are easier to machine and have an improved hardness when they are produced in the following way:

An aluminium alloy is filled into a casting mould at a temperature of 720° to 740°C, then the aluminium alloy is subjected to cooling at a cooling rate of 0.1 - 10 K s⁻¹ and after cooling to room temperature a thermal treatment is carried out consisting of a solution heat treatment at 530°C for 5 hours, chilling in water at 80°C and artificial ageing at a temperature of 160 to 200°C for 6 hours.

Several examples of embodiments are given below, from which the processing advantages become obvious which result from an increased hardness and a better machinability combined therewith as well as a reduced vulnerability to corrosion while the good mechanical properties are maintained (Table 1). A nickel-aluminium alloy known from the Aluminium-Taschenbuch 14th Edition,

page 35 was examined as comparison example to the alloys according to the present invention. It was found that only a low thermal conductivity could be measured due to the high eutectic portion.

The assessment of the processibility is based on a comparison of hardness wherein the individual values were obtained in an indentation test according to Brinell. For the alloy according to the present invention a hardness of 100 to 105 HB was measured in contrast to 85 to 90 HB for the compared alloy.

The particularly high degree of hardness measured for the alloy of the invention could be achieved by a special artificial ageing as it is defined in Claim 4. In this treatment the following parameters were observed:

casting temperature: 730°C

cooling rate: approx. 1 to 5 K/s

solution heat treatment at 530°C for 5 hours

chilling in water of 80°C

artificial ageing at 180°C for 6 hours

A corrosion comparison with a copper-containing alloy (0.5 % copper of alloy No.6) showed a distinctive improvement of the corrosion resistance (in view of the State of the Art) and especially in view of the conventionally used alloys, such as alloy No. 5 which has so far been used for the production of cylinder heads and motor block castings. Thus, it may be assumed that the use of the alloy according to the present invention results in achieving a substantial improvement of the corrosion properties when copper is replaced by nickel, wherein the special thermal treatment as previously described and the concentration limits as defined in Claim 1 helped in the advantageous formation of the phases (i.e. in the extensive spheroidizing of the phases) of the aluminium-copper type and the magnesium-silicon type.

The obtained degrees of hardness were not only decisively in-

fluenced by the individually used phase types but also by their distribution and fineness as well as their amounts measured in volume percent. The amount was determined by means of quantitative image analysis of statistically distributed sections, whereas the phase types were determined by micro probe examination. While State of the Art alloy No. 6 (Table 1) contained only 0.5 vol.% of the Cu-containing phase, the alloy of the present invention shows finely distributed intermetallic phases of an average length of 20 μm maximum of the types aluminium-nickel, aluminium-copper and aluminium-iron-manganese, wherein the volume proportion was at least 1 vol.% which is to be considered an important reason for the improvement in thermal strength.

Claims

1. A cylinder head and motor block casting, comprising an aluminium alloy having the following composition:

Si 6.80 - 7.20

Fe 0.35 - 0.45

Cu 0.30 - 0.40

Mn 0.25 - 0.30

Mg 0.35 - 0.45

Ni 0.45 - 0.55

Zn 0.10 - 0.15

Ti 0.11 - 0.15

the remainder being aluminium as well as unavoidable impurities with a maximum content of 0.05 each, but not more than a maximum of 0.15 impurities in all,

furthermore characterized in comprising at least 1 vol.% of the following phases of the aluminium-nickel type, aluminium-copper type, aluminium-manganese type, aluminium-iron type and mixed phases of the aforesaid types.

2. A cylinder head and motor block casting according to Claim 1,

characterized in having the following crystalline structure

- a) an alpha aluminium matrix structure having 40 to 60 vol.%
- b) an eutectic aluminium-silicon phase having 40 to 55 vol.%
- c) further phases comprising 1 to 3 vol.% of aluminium and alloying constituents iron, copper, magnesium, nickel and silicon.

3. A cylinder head and motor block casting according to any of the preceding claims,

characterized in that the ratios of the aluminium alloy elements are as follows:

- a) Si : Fe : Cu = 7 : 0.4 : 0.35
- b) Fe : Mn = 1 : 0.7
- c) Ni : Mg : Cu = 5 : 4 : 3.5

4. A method for manufacturing a cylinder head and motor block casting according to one of the preceding claims,

characterized in

that

- a) an aluminium alloy is filled into a casting mould at a temperature of 720° to 740°C,
- b) the aluminium alloy is subjected to cooling at a cooling rate of 0.1 to 10 K s⁻¹,
- c) a thermal treatment is carried out under the following conditions after the cooling to room temperature is accomplished:
solution heat treatment at 530°C for 5 hours, chilling in water at 80°C and artificial ageing at a temperature of 160 to 200°C for 6 hours.

													Distribution of phases			
	Si	Fe	Cu	Mn	Mg	Ni	Zn	Ti	Si:Fe:Cu	Fe:Mn	Mg:Ni	Hardness HB	Corro- sion			
Invent. Alloy 1	6.8	0.35	0.30	0.25	0.35	0.45	0.10	0.11	7 : 0.4 : 0.35	1 : 0.7	4 : 5	105	+			
Invent. Alloy 2	6.93	0.38	0.33	0.26	0.38	0.48	0.12	0.12				100	+			
Invent. Alloy 3	7.07	0.41	0.37	0.28	0.42	0.52	0.13	0.13				102	+			
Invent. Alloy 4	7.20	0.45	0.40	0.30	0.45	0.55	0.15	0.15				104	+			
Compar. Alloy 5	8.86	0.650	2.40	0.520	0.27	0.010	0.270	0.121	-	-	-	90	-			
Compar. Alloy 6	7.13	0.125	0.50	0.005	0.36	0.004	0.006	0.007	-	-	-	85	-			