

Components for drinking water pipes, and method for manufacturing same

Field

5 **[0001]** Components suitable for plumbing installations, for example for drinking water pipes, and methods for manufacturing same are provided. Such components include for example, coupling parts, angular parts, elbow parts, T-piece parts, distributor parts, fittings and valves. The components may also find utility in other plumbing applications such as in central heating, ventilation or air-conditioning systems.

10 Background

[0002] The use of small quantities of lead in copper alloys, such as brasses and bronzes, used to form plumbing components provided beneficial properties to the resulting alloys, for example improved machining properties, thereby allowing the production of complex parts.

15 **[0003]** The materials from which components for plumbing installations are made, particularly those carrying media such as drinking water must be resistant to corrosion for many years. In addition, in order to be able to manufacture such components, the alloys from which said components are made must be easily and economically processed and have good machinability. The alloys must be able to withstand the mechanical strains which the components are likely to be exposed to during manufacture, storage, transport, installation, and during the working life of
20 the installation.

[0004] The presence of heavy metals such as lead and tin in alloys used for plumbing components could pose a health risk, thus there are regulatory limits on the amounts of certain metals that are present in alloys for use in the manufacture of plumbing components for drinking water.

25 **[0005]** Copper-tin alloys such as CC499K (EN symbol for casting is CuSn5Zn5Pb2-C), which comprises 84 wt% to 88 wt% Cu, 4 wt% to 6 wt% Sn, 4 wt% to 6 wt% Zn, 3 wt% Pb and 0.10 W Sb, have been widely used to form plumbing components. This alloy has good mechanical and machining properties. CC499K is suitable for sand casting, die casting, centrifugal casting and continuous casting. CC499K has a tensile strength of about 220 MPa and an elongation of about
30 13% according to BE EN 1982. The 0.2% proof stress is 110 MPa. CC499K is approved for drinking water contact under the 4MS initiative.

[0006] European patent number EP1446510 discloses use of a non-corrosive copper-zinc alloy for drinking water shaped parts. EP1446510 describes a corrosion-resistant copper-zinc alloy for drinking water moulded parts, which is composed of the following alloy components: a) 23 to 32 wt% zinc; b) 0.01 to 0.3 wt% at least one of the elements tin, iron, nickel, aluminium and silicon;
5 c) 0.7 to 1.5 wt% lead; d) balance copper including production-related impurities as a material for the production, and the residual copper content being based on the sum of the components of the respective mixture components in a) to c).

[0007] The migration of elements such as lead and tin into media conveyed through plumbing components is not desirable, particularly when said media is for human consumption. The
10 European Drinking Water Directive requires that potable water comprise a maximum of 10 micrograms of lead per litre, and this limit must be reduced to a maximum of 5 micrograms of lead by 2036. In order to meet these limits, the replacement of lead containing plumbing components in houses and buildings is required.

[0008] US patent application publication number US2007158004 relates to a method for
15 producing components, such as fittings, valves, and pipes suitable for conveying media- or drinking water, which components purportedly exhibit low migration of metal ions into the medium. The method involves continuously casting an ingot or rod from a copper alloy wherein the alloy has the following components in wt%: $2 \text{ wt}\% \leq \text{Si} \leq 4.5 \text{ wt}\%$, $1 \text{ wt}\% \leq \text{Zn} \leq 17 \text{ wt}\%$, $0.05 \text{ wt}\% \leq \text{Mn} \leq 0.6 \text{ wt}\%$, unavoidable accompanying elements to a maximum of 0.5 wt% in total, preferably
20 to a maximum of 0.3 wt% in total, the remainder is copper and the ingot or the rod for producing the component is subjected at least to one cold and/or hot forming process. US2007158004 includes a single example composition which comprises 3.5 wt% Si, 1.6 wt% Zn and 0.5 wt% Mn, unavoidable accompanying elements are present to a maximum of 0.5 wt% and the remainder is copper. The exemplified composition had lower lead, nickel, copper and zinc release than a red
25 brass alloy comprising 5.5 wt% Zn, 4.5 wt% Sn, 3 wt% Pb, 0.5 wt% Ni and the remainder being copper. The tensile strength of such copper alloys is approximately 300 MPa, and the elongation is approximately 16%. The alloy does not have good machinability and cannot be used for forming.

[0009] European patent number EP1045041 discloses and claims a lead-free free-cutting
30 copper alloy which comprises 69 to 79 percent, by weight, of copper; 2.0 to 4.0 percent, by weight, of silicon; at least one element selected from among 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 percent, by weight, of tellurium, and 0.02 to 0.4 percent, by weight, of selenium; and the remaining percent, by weight, of zinc. Thus, EP1045041 discloses copper alloys comprising approximately 16 wt% to approximately 29 wt% zinc. The copper alloy of EP1045041 has been
35 criticised with respect to corrosion resistance, in addition, the alloys contain elements which are not suitable for drinking water pipes.

[0010] US patent application publication number US2009/0214380 discloses and claims the use of a copper alloy for the manufacture of components for gas or water lines which carry media, in particular drinking water lines as well as fittings and valves of the same, wherein the copper alloy comprises, in wt%: $2.8 \leq \text{Si} \leq 4.5$; $1 \leq \text{Zn} \leq 15$; $0.05 \leq \text{Mn} \leq 2$; $80 \leq \text{Cu} \leq 96.95$ optionally further comprising: $0.05 \leq \text{Al} \leq 0.5$; $0.05 \leq \text{Sn} \leq 2$; $0.0005 \leq \text{Zr} \leq 0.05$; $0.01 \leq \text{P} \leq 0.2$; and unavoidable impurities.

[0011] US patent application publication number US2008/0318079 discloses plumbing valves, fittings and other water handling devices manufactured of silicon bronze having a lead content below 0.2%. The silicon bronze alloy described therein C87800 consists of in wt%:

TABLE 1

	Cu	Al	Sb	As	Fe	Pb	Mg	Mn	Ni ⁽¹⁾	P	Si	S	Sn	Zn
Min/Max	80.0 min	.15	.05	.05	.15	.15	.01	.15	.20	.01	3.8-4.2	.05	.25	12.0-16.0

A preferred C87800 alloy comprised about 82wt% copper, 4wt% silicon and 14wt% zinc. Alternatively, the silicon bronze alloy C87610 may be used:

TABLE 2

	Cu	Fe	Pb	Mn	Si	Zn
Min/Max	90.0 min	.20	.20	.25	3.0-5.0	3.0-5.0

A preferred C87610 alloy comprises about 92wt% copper, about 4wt% silicon and about 4 wt% zinc. C87800 has an elongation of up to about 25%, and C87610 has an elongation of up to about 20%.

[0012] It would be desirable to provide an alloy which has reduced lead content, has low ion migration to a medium such as drinking water, is suitable for both forming and casting, has good machinability, and is suitable for soldering. It would be particularly desirable to provide an alloy having the aforementioned properties and having increased tensile strength and elongation properties. These and other desires are provided by the present invention.

SUMMARY

[0013] In one aspect, the present invention provides a Cu-Zn-Si alloy comprising, consisting essentially of, or consisting of the following components in weight percent:

$11.0 \leq \text{Zn} \leq 13.0$;

5 $2.5 \leq \text{Si} \leq 3.7$;

$0.1 \leq \text{Fe} \leq 0.5$;

$0.1 \leq \text{Mn} \leq 0.2$;

wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q,

10 where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,

wherein $36 \leq Q \leq 48$;

wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni;

wherein the Cu-Zn-Si alloy comprises no more than 0.2 wt% Al;

wherein the Cu-Zn-Si alloy comprises no more than 0.03 wt% P;

15 wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less, wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and

wherein the balance is copper, for example, $82.0 \leq \text{Cu} \leq 86.3$, suitably $82.0 \leq \text{Cu} \leq 86.0$, such as $82.0 \leq \text{Cu} \leq 85.8$, preferably $82.0 \leq \text{Cu} \leq 85.0$, for example $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq 84.5$, such as $83.0 \leq \text{Cu} \leq 84.5$;

20 said Cu-Zn-Si alloy having a tensile strength as determined in accordance with ISO 6892-1:2009 of 300 MPa or more; preferably 400 MPa or more, and

said alloy having an elongation at fracture of 25% or more, preferably 30% or more, more preferably 40% or more as determined in accordance with ISO6892-1:2009.

[0014] Suitably, the Cu-Zn-Si alloy comprises in weight percent: $2.5 \leq \text{Si} \leq 3.5$.

25 **[0015]** Suitably, $38 \leq Q \leq 44$.

[0016] For example, the Cu-Zn-Si alloy may comprise in weight percent: $2.5 \leq \text{Si} \leq 3.2$; and $36 \leq Q \leq 47$, preferably $38 \leq Q \leq 45$, such as from $38 \leq Q \leq 42$. Such a silicon content and Q value are particularly advantageous when the alloy is continuously cast.

[0017] Suitably, the Cu-Zn-Si alloy comprises in weight percent: $2.5 \leq \text{Si} \leq 3.2$; and $36 \leq Q \leq 47$, preferably $38 \leq Q \leq 45$, such as from $38 \leq Q \leq 42$, and said alloy is continuously cast.

[0018] In another embodiment, the Cu-Zn-Si alloy may comprise in weight percent:

$2.7 \leq \text{Si} \leq 3.5$; and where $37 \leq Q \leq 48$, preferably $40 \leq Q \leq 46$, such as from $40 \leq Q \leq 44$. Such a silicon content and Q value are particularly advantageous when alloy is gravity cast.

[0019] Suitably, the Cu-Zn-Si alloy may comprise in weight percent:

$2.7 \leq \text{Si} \leq 3.5$; and where $37 \leq Q \leq 48$, preferably $40 \leq Q \leq 46$, such as from $40 \leq Q \leq 44$ and is gravity cast.

[0020] Suitably, the Cu-Zn-Si alloy comprises a zinc content in the range:

$11.5 \leq \text{Zn} \leq 13.0$, such as $12.0 \leq \text{Zn} \leq 13.0$.

[0021] The Cu-Zn-Si alloy may comprise a manganese content in the range:

$0.1 \leq \text{Mn} \leq 0.15$, preferably in the range: $0.10 \leq \text{Mn} \leq 0.14$.

[0022] Preferably, the Cu-Zn-Si alloy is free of As and/or Sb.

[0023] The Cu-Zn-Si alloy may have a tensile strength as determined in accordance with ISO 6892-1:2009 of 350 MPa or more, preferably 380 MPa or more, even more preferably 400 MPa or more, such as 450 MPa or more.

[0024] Suitably, the Cu-Zn-Si alloy has a true solid state density in the range of from 8.0 kg/m^3 to 8.29 kg/m^3 , preferably from 8.0 to 8.28 kg/m^3 , suitably from 8.18 to 8.28 kg/m^3 . The true solid state density may be measured in accordance with BS ISO 12154.

[0025] In another aspect, the present invention provides components for drinking-water pipes, namely valves and fittings for same, manufactured from a Cu-Zn-Si alloy described herein which comprises, consists essentially of or consists of the following in weight percent:

$11.0 \leq \text{Zn} \leq 13.0$;

$2.5 \leq \text{Si} \leq 3.7$;

$0.1 \leq \text{Fe} \leq 0.5$;

$0.1 \leq \text{Mn} \leq 0.2$, e.g. $0.1 \leq \text{Mn} \leq 0.15$, , preferably $0.10 \leq \text{Mn} \leq 0.14$.

wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q,

where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,

5 wherein $36 \leq Q \leq 48$;

wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni;

wherein the Cu-Zn-Si alloy comprises no more than 0.2 wt% Al;

wherein the Cu-Zn-Si alloy comprises no more than 0.03 wt% P;

10 wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less, wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and

wherein the balance is copper, for example, $82.0 \leq \text{Cu} \leq 86.3$, suitably $82.0 \leq \text{Cu} \leq 86.0$, such as $82.0 \leq \text{Cu} \leq 85.8$, preferably $82.0 \leq \text{Cu} \leq 85.0$, for example $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq 84.5$, such as $83.0 \leq \text{Cu} \leq 84.5$;

15 said Cu-Zn-Si alloy having a tensile strength as determined in accordance with ISO 6892-1:2009 of 300 MPa or more; and

said alloy having an elongation at fracture of 25% or more, preferably 30% or more, more preferably 40% or more as determined in accordance with ISO6892-1:2009.

[0026] In a still further aspect, the present invention provides a method for manufacturing components for drinking-water pipes, namely valves and fittings for same, comprising:

20 (i) providing a Cu-Zn-Si alloy as described herein comprising, consisting essentially of, or consisting of the following in weight percent:

$11.0 \leq \text{Zn} \leq 13.0$;

$2.5 \leq \text{Si} \leq 3.7$;

$0.1 \leq \text{Fe} \leq 0.5$;

25 $0.1 \leq \text{Mn} \leq 0.2$, e.g. $0.1 \leq \text{Mn} \leq 0.15$, , preferably $0.10 \leq \text{Mn} \leq 0.14$;

wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q,

where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,

wherein $36 \leq Q \leq 48$;

wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni;

wherein the Cu-Zn-Si alloy comprises no more than 0.2 wt% Al;

5 wherein the Cu-Zn-Si alloy comprises no more than 0.03 wt% P;

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less, wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and

wherein the balance is copper, for example, $82.0 \leq \text{Cu} \leq 86.3$, suitably $82.0 \leq \text{Cu} \leq 86.0$, such as $82.0 \leq \text{Cu} \leq 85.8$, preferably $82.0 \leq \text{Cu} \leq 85.0$, for example $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq 84.5$,
10 such as $83.0 \leq \text{Cu} \leq 84.5$;

said Cu-Zn-Si alloy having a tensile strength as determined in accordance with ISO 6892-1:2009 of 300 MPa or more; and

said alloy having an elongation at fracture of 25% or more, preferably 30% or more, more preferably 40% or more as determined in accordance with ISO 6892-1:2009; and

15 (ii) Processing said alloy to form said components.

[0027] Processing said alloy to form components as described herein may include continuous casting said alloy, and/or one or more metal forming steps.

[0028] Processing said alloy to form components as described herein may include gravity casting said alloy, for example sand casting or die casting said alloy.

20 **[0029]** Processing said alloy to form components as described herein may include pressurised die casting, e.g. high-pressure die casting.

[0030] Processing said alloy to form components as described herein may include one or more metal forming steps, for example forging or rolling said alloy.

25 **[0031]** Processing said alloy to form components as described herein may include one or more machining steps.

[0032] The processing of the Cu-Zn-Si alloy may involve heating the copper alloy to a temperature in the range of from 800 to 1300°C, preferably from 1000°C to 1300°C in one or more processing steps. For example, in a continuous casting process the Cu-Zn-Si alloy may be heated

to a temperature in the range of from 1000°C to 1150°C. In a gravity casting process the Cu-Zn-Si alloy may be heated to a temperature in the range of from 1200°C to 1300°C.

5 **[0033]** Suitably, when the manufacture of the components described herein involves continuous casting, the Cu-Zn-Si alloy comprises in weight percent: $2.5 \leq \text{Si} \leq 3.2$; and suitably $36 \leq Q \leq 47$, preferably $38 \leq Q \leq 45$, such as $38 \leq Q \leq 42$.

[0034] Suitably, when the manufacture of the components described herein involves gravity casting, such as sand casting or die casting, the Cu-Zn-Si alloy comprises in weight percent: $2.7 \leq \text{Si} \leq 3.5$; and suitably $37 \leq Q \leq 48$, preferably $40 \leq Q \leq 46$; such as from $40 \leq Q \leq 44$.

10 **[0035]** The Cu-Zn-Si alloy has a tensile strength as determined in accordance with ISO 6892-1:2009 of 350 MPa or more, preferably 380 MPa or more, even more preferably 400 MPa or more, such as 450 MPa or more.

15 **[0036]** The method of any one of claims 10 to 15, wherein the Cu-Zn-Si alloy has a true solid state density in the range of from 8.0 kg/m³ to 8.29 kg/m³, preferably from 8.0 to 8.28 kg/m³, suitably from 8.18 to 8.28 kg/m³. The true solid state density may be measured in accordance with BS ISO 12154.

[0037] The present disclosure also provides, a Cu-Zn-Si alloy comprising, consisting essentially of or consisting of the following components in weight percent:

$11.0 \leq \text{Zn} \leq 13.0$, optionally $11.5 \leq \text{Zn} \leq 13.0$, such as $12.0 \leq \text{Zn} \leq 13.0$;

$2.4 \leq \text{Si} \leq 4.1$;

20 $0.1 \leq \text{Fe} \leq 0.5$;

optionally, $0.1 \leq \text{Mn} \leq 0.2$;

wherein the sum of the weight percentage of Zn and ten times the weight percentage of Si amounts to a combined weight percentage Q,

where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,

25 wherein $35 \leq Q \leq 52$;

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,

wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb.

[0038] Also disclosed herein are components for drinking-water pipes, namely valves and fittings for same, manufactured from a Cu-Zn-Si alloy comprising the following components in weight percent:

$80 \leq \text{Cu} \leq 88$, preferably $81.0 \leq \text{Cu} \leq 86.5$;

5 $11.0 \leq \text{Zn} \leq 13.0$, optionally $11.5 \leq \text{Zn} \leq 13.0$, such as $12.0 \leq \text{Zn} \leq 13.0$;

$2.4 \leq \text{Si} \leq 4.1$;

$0.1 \leq \text{Fe} \leq 0.5$;

optionally, $0.1 \leq \text{Mn} \leq 0.2$;

10 wherein the sum of the weight percentage of Zn and ten times the weight percentage of Si amounts to a combined weight percentage Q,

where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,

wherein $35 \leq Q \leq 52$;

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,

wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb.

15 **[0039]** In another aspect, the present disclosure provides a method for manufacturing components for drinking-water pipes, namely valves and fittings for same, comprising:

(i) Providing a Cu-Zn-Si alloy comprising the following components in weight percent:

$80 \leq \text{Cu} \leq 88$, preferably $81.0 \leq \text{Cu} \leq 86.5$;

$11.0 \leq \text{Zn} \leq 13.0$, optionally $11.5 \leq \text{Zn} \leq 13.0$, such as $12.0 \leq \text{Zn} \leq 13.0$;

20 $2.4 \leq \text{Si} \leq 4.1$;

$0.1 \leq \text{Fe} \leq 0.5$;

optionally, $0.1 \leq \text{Mn} \leq 0.2$;

wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q:

25 where $Q = [\text{Zn}] + (10 \times [\text{Si}])$

wherein $35 \leq Q \leq 52$; and

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,

wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and

(ii) processing said alloy to form said components.

[0040] The Cu-Zn-Si alloy of the present disclosure may comprise in weight percent:

- 5 $80.5 \leq \text{Cu} \leq 87$, preferably $81.0 \leq \text{Cu} \leq 86.5$, more preferably $81.5 \leq \text{Cu} \leq 86.3$, even more preferably $82.0 \leq \text{Cu} \leq 86.0$, such as $82.0 \leq \text{Cu} \leq 85.8$, such as $82.0 \leq \text{Cu} \leq 85.0$, such as $82.2 \leq \text{Cu} \leq 85.0$.

[0041] It is particularly preferred when the amount of copper in the Cu-Zn-Si alloy of the present invention is in the range of from $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq 84.5$, such as $83.0 \leq \text{Cu} \leq 84.5$.

- 10 **[0042]** The Cu-Zn-Si alloy may for example comprise in weight percent: $2.5 \leq \text{Si} \leq 3.7$, preferably $2.5 \leq \text{Si} \leq 3.5$.

- [0043]** The Cu-Zn-Si alloy may have a tensile strength as determined in accordance with ISO 6892-1:2009 of 300 MPa or more, preferably 350 MPa or more, even more preferably 380 MPa or more, even more preferably 400 MPa or more, such as 450 MPa or more. For example, the
15 Cu-Zn-Si alloy may have a tensile strength in the range of from 300 MPa to 650 MPa, such as from 350 MPa to 650 MPa, preferably 380 MPa to 600 MPa as determined in accordance with ISO 6892-1:2009, for example from 400 MPa to 600 MPa, such as from 450 MPa to 600 MPa.

- [0044]** The Cu-Zn-Si alloy suitably has an elongation at fracture of 15% or more, suitably 20% or more, preferably 25% or more as determined in accordance with ISO 6892-1:2009, such as
20 30% or more, or 35% or more. For example, the Cu-Zn-Si alloy may have an elongation at fracture in the range of from 25% to 65%, such as from 30% to 60%, or 35% to 60%.

- [0045]** Suitably, the Cu-Zn-Si alloy may have a tensile strength of 350 MPa or more and an elongation at fracture of 25% or more as determined in accordance with ISO 6892-1:2009. In some embodiments the Cu-Zn-Si alloy has a tensile strength of 380 MPa or more and an
25 elongation at fracture in the range of from 25% to 65%. In particularly preferred embodiments, the Cu-Zn-Si alloy (and components made therefrom) has a tensile strength of from 380 MPa to 650 MPa, such as from 400 to 600 MPa, or 450 MPa to 600 MPa and the elongation at fracture is 25% to 65%, such as 30% to 60% or 35% to 60% as determined in accordance with ISO 6892-1:2009.

- 30 **[0046]** Suitably, the Cu-Zn-Si alloy comprises no more than 0.1 wt% Sn, more suitably, no more than 0.06 wt% Sn.

[0047] The Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni.

[0048] The Cu-Zn-Si alloy may comprise up to 0.2 wt% Al, e.g. 0.001 wt% to 0.2 wt% Al.

[0049] The Cu-Zn-Si alloy may comprise up to 0.03 wt% P, e.g. 0.001 wt% to 0.03 wt% P.

[0050] Suitably, the Cu-Zn-Si alloy is free of As.

5 [0051] The Cu-Zn-Si alloy may alternatively or additionally be free of one or more of Sb, Bi, Te and Se. For example, the Cu-Zn-Si alloy may be free of As, Sb, Bi, Te and Se.

DETAILED DESCRIPTION

[0052] As outlined above, disclosed herein is a Cu-Zn-Si alloy comprising, consisting essentially of, or consisting of the following components in weight percent:

$11.0 \leq \text{Zn} \leq 13.0$;

10 $2.5 \leq \text{Si} \leq 3.7$;

$0.1 \leq \text{Fe} \leq 0.5$;

$0.1 \leq \text{Mn} \leq 0.2$, such as $0.1 \leq \text{Mn} \leq 0.15$, preferably $0.10 \leq \text{Mn} \leq 0.14$;

wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q,

15 where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,

wherein $36 \leq Q \leq 48$;

wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni;

wherein the Cu-Zn-Si alloy comprises no more than 0.2 wt% Al;

wherein the Cu-Zn-Si alloy comprises no more than 0.03 wt% P;

20 wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less, wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and

wherein the balance is copper, for example, $82.0 \leq \text{Cu} \leq 86.3$, preferably $82.0 \leq \text{Cu} \leq 85.0$, for example $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq 84.5$, such as $83.0 \leq \text{Cu} \leq 84.5$;

25 said Cu-Zn-Si alloy having a tensile strength as determined in accordance with ISO 6892-1:2009 of 300 MPa or more; preferably 400 MPa or more, and

said alloy having an elongation at fracture of 25% or more, preferably 30% or more, more preferably 40% or more as determined in accordance with ISO6892-1:2009.

5 [0053] The Cu-Zn-Si alloy is particularly suitable for manufacture of components such as plumbing fittings, for example, components for drinking water pipes i.e. pipes suitable for conveying drinking water or other media for human consumption for example, coupling parts, angular parts, elbow parts, T-piece parts, distributor parts, fittings and valves. Of course, the components may also be used in other plumbing settings, for example in central heating, ventilation or air-conditioning systems.

10 [0054] Advantageously, the components are lead free and have low ion migration into media such as drinking water which is conveyed through the components.

[0055] The zinc content of 11.0 wt% to 13.0 wt% influences elongation and tensile strength. If the zinc content is lower than about 11 wt%, the elongation is reduced. If the zinc content exceeds about 13 wt% the tensile strength deteriorates. In some embodiments, the zinc content is in the range of from 11.5 wt% to 13.0 wt%, such as from 12.0 wt% to 13.0 wt%.

15 [0056] The silicon content of 2.5 wt% to 3.7 wt% influences corrosion resistance, castability, and abrasion resistance. The corrosion rate may be between 0.02 and 0.002 mm/year as determined in accordance with ISO 16151:2018. If the silicon content is lower than about 2.5 wt%, these properties are reduced. If the silicon content exceeds about 3.7 wt% these properties deteriorate. In some embodiments, the silicon content is in the range of from 2.5 wt% to 3.5 wt%.

20 [0057] Importantly, the relationship between the zinc content and the silicon content significantly influences tensile strength and elongation when the alloy is processed under different processing conditions.

25 [0058] For example, the alloy of the present invention when processed in a continuous casting or metal forming process has an optimal relationship between the amount of zinc and silicon which is defined by Q:

where $Q = [\text{Zn}] + (10 \times [\text{Si}])$, and wherein $2.5 \leq \text{Si} \leq 3.5$, such as from $2.5 \leq \text{Si} \leq 3.2$; and where $36 \leq Q \leq 47$, preferably $38 \leq Q \leq 42$.

30 [0059] In a continuous casting or metal forming process if Q is less than about 36 a reduction in tensile strength is observed, whereas if Q is greater than about 47, a reduction in elongation is observed. Advantageously when Q is in the range of from about 38 wt% to about 42 wt% optimal tensile strength and elongation are achieved for components as described in the present invention.

[0060] Accordingly, one aspect of the present invention provides components for drinking water pipes, namely valves and fittings for same, manufactured by continuous casting or metal forming a Cu-Zn-Si alloy comprising the following components in weight percent:

$$11.0 \leq \text{Zn} \leq 13.0$$

5 $2.5 \leq \text{Si} \leq 3.5$

$$0.1 \leq \text{Fe} \leq 0.5$$

$$0.1 \leq \text{Mn} \leq 0.2, \text{ e.g. } 0.1 \leq \text{Mn} \leq 0.15, \text{ preferably in the range: } 0.10 \leq \text{Mn} \leq 0.14;$$

wherein the sum of the weight percentage of Zn and ten times the weight percentage of Si amounts to a combined weight percentage Q,

10 where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,

$$\text{wherein } 36 \leq Q \leq 47, \text{ preferably } 38 \leq Q \leq 42,$$

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,

wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb, preferably no more than 0.05 wt% Pb;

15 wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni;

wherein the Cu-Zn-Si alloy comprises no more than 0.2 wt% Al;

wherein the Cu-Zn-Si alloy comprises no more than 0.03 wt% P;

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less, wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and

20 wherein the balance is copper, for example, $82.0 \leq \text{Cu} \leq 86.3$, preferably $82.0 \leq \text{Cu} \leq 85.0$, for example $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq 84.5$, such as $83.0 \leq \text{Cu} \leq 84.5$;

said Cu-Zn-Si alloy having a tensile strength as determined in accordance with ISO 6892-1:2009 of 300 MPa or more; preferably 400 MPa or more, and

25 said alloy having an elongation at fracture of 25% or more, preferably 30% or more, more preferably 40% or more as determined in accordance with ISO 6892-1:2009.

[0061] When the alloy of the present invention is processed in a gravity casting process, the optimal relationship between the amount of zinc and silicon is defined by Q:

30 where $Q = [\text{Zn}] + (10 \times [\text{Si}])$, and wherein $2.7 \leq \text{Si} \leq 3.5$, such as $2.8 \leq \text{Si} \leq 3.2$; and where $37 \leq Q \leq 48$, preferably $40 \leq Q \leq 46$.

[0062] In a gravity casting process, such as a sand casting process or a die casting process, if Q is less than about 37 a reduction in tensile strength is observed, whereas if Q is greater than about 48, a reduction in elongation is observed. Advantageously when Q is in the range of from about 40 wt% to about 46 wt%, optimal elongation and tensile strength is achieved for gravity castings.

[0063] Accordingly, another aspect of the invention provides components for drinking water pipes, namely valves and fittings for same, manufactured by gravity casting, such as sand casting or die casting, a Cu-Zn-Si alloy of the present invention comprising the following components in weight percent:

$$11.0 \leq \text{Zn} \leq 13.0$$

$$2.7 \leq \text{Si} \leq 3.5$$

$$0.1 \leq \text{Fe} \leq 0.5$$

$$0.1 \leq \text{Mn} \leq 0.2, \text{ e.g. } 0.1 \leq \text{Mn} \leq 0.15, \text{ preferably in the range: } 0.10 \leq \text{Mn} \leq 0.14;$$

wherein the sum of the weight percentage of Zn and ten times the weight percentage of Si amounts to a combined weight percentage Q,

$$\text{where } Q = [\text{Zn}] + (10 \times [\text{Si}]),$$

wherein $37 \leq Q \leq 48$, preferably $40 \leq Q \leq 46$,

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,

wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb.

[0064] The Cu-Zn-Si alloy of the present invention comprises iron in an amount of from 0.1 wt% to 0.5 wt%. When the amount of iron is lower than about 0.1 wt% cracking proneness when heated increases, ductility reduces and the fine-grained uniform structure is not observed. If the amount of iron is greater than about 0.5 wt% cracking proneness when heated increases, ductility reduces and the fine-grained uniform structure is not observed.

[0065] The Cu-Zn-Si alloy of the present invention comprises manganese in an amount of 0.1 wt% to 0.2 wt%.

[0066] When the amount of manganese is less than about 0.1 wt% a reduction in corrosion resistance is observed. If the amount of manganese is greater than about 0.2 wt% a reduction in corrosion resistance is observed. The amount of manganese is suitably in the range of from 0.1

wt% to 0.15 wt%, preferably in the range of from 0.1 wt% to 0.14 wt%. Elongation at fracture is advantageously further enhanced when the amount of manganese is within this range.

5 **[0067]** Suitably, the content of the four main alloying elements i.e. Zn, Si, Fe and Mn, and excluding copper is between 13.7 and 16.9 wt%, such as from 13.7 and 16.6 wt% for components manufactured using continuous casting or metal forming.

[0068] Suitably, the content of the four main alloying elements i.e. Zn, Si, Fe and Mn, and excluding copper is between 13.9 and 17.3 wt%, such as from 14.1 to 17.3 wt% or 13.9 and 17.2 wt% for components manufactured using gravity casting, such as sand casting or die casting.

10 **[0069]** The components of the invention are Cu-Zn-Si alloy casting components, such as Cu-Zn-Si alloy: continuous castings, gravity castings, sand castings, or die castings.

[0070] Suitably, the methods described herein may include one or more annealing steps. Advantageously, such annealing can enhance the ductility of the Cu-Zn-Si alloy, and components made therefrom. For example, the Cu-Zn-Si alloy may be annealed by heating to a temperature in the range of from 700 to 900 °C.

15 **[0071]** For the purpose of clarity and concise description, features are described herein as part of the same or separate embodiments, however, it will be appreciated that the scope of the invention may include embodiments having combinations of all or some of the features described.

20 **[0072]** It is appreciated that the weight of the components of the alloys of the invention add up to 100 wt%, thus for example, when a composition specifies the balance is copper, this means that the remainder of the composition to make up 100 wt% is copper i.e. the balance is copper up to 100 wt%.

[0073] The invention will be more readily appreciated by a review of the examples, which follow. The examples are not limiting on the scope of the invention, which is defined in the claims.

Embodiments

1. Components for drinking-water pipes, namely valves and fittings for same, manufactured from a Cu-Zn-Si alloy comprising the following components in weight percent:
80 ≤ Cu ≤ 88, preferably 81.0 ≤ Cu ≤ 86.5
5 11.0 ≤ Zn ≤ 13.0
2.4 ≤ Si ≤ 4.1
0.1 ≤ Fe ≤ 0.5
optionally, 0.1 ≤ Mn ≤ 0.2;
wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q,
10 (where Q = [Zn] + (10 x [Si])),
wherein 35 ≤ Q ≤ 52;
wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,
wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb.
15
2. A method for manufacturing components for drinking-water pipes, namely valves and fittings for same, comprising:
- (i) Providing a Cu-Zn-Si alloy comprising the following components in weight percent:
20 80 ≤ Cu ≤ 88, preferably 81.0 ≤ Cu ≤ 86.5,
11.0 ≤ Zn ≤ 13.0
2.4 ≤ Si ≤ 4.1
0.1 ≤ Fe ≤ 0.5
optionally, 0.1 ≤ Mn ≤ 0.2;
25 wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q:
where Q = [Zn] + (10 x [Si])
wherein 35 ≤ Q ≤ 52; and
wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,
30 wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and
(ii) processing said alloy to form said components.
3. The method of embodiment 2, wherein step (ii) includes continuous casting said alloy, and/or wherein step (ii) includes one or more metal forming steps.
- 35 4. The method of embodiment 2, wherein step (ii) includes gravity casting said alloy, for example sand casting or die casting said alloy.

5. The method of embodiment 2, wherein step (ii) includes one or more metal forming steps, for example forging or rolling said alloy.
6. The method of any one of embodiment 2 to 5, wherein step (ii) further includes one or more machining steps.
- 5 7. The method of any one of embodiments 2 to 6, wherein the Cu-Zn-Si alloy comprises in weight percent:
- $80.5 \leq \text{Cu} \leq 87$,
- preferably $81.0 \leq \text{Cu} \leq 86.5$,
- more preferably $81.5 \leq \text{Cu} \leq 86.3$,
- 10 even more preferably $82.0 \leq \text{Cu} \leq 86.0$, such as $82.0 \leq \text{Cu} \leq 85.0$.
8. The method of any one of embodiments 2 to 7, wherein the Cu-Zn-Si alloy comprises in weight percent:
- $2.5 \leq \text{Si} \leq 3.7$, preferably $2.5 \leq \text{Si} \leq 3.5$.
9. The method of any one of embodiments 2 to 8, wherein step (ii) involves heating the
- 15 Cu-Zn-Si alloy to a temperature in the range of from 800 to 1300°C, in one or more processing steps.
10. The method of embodiment 3, wherein the Cu-Zn-Si alloy comprises in weight percent:
- $2.5 \leq \text{Si} \leq 3.5$, such as from $2.5 \leq \text{Si} \leq 3.2$; and
- where $36 \leq Q \leq 47$, preferably $38 \leq Q \leq 45$, such as from $38 \leq Q \leq 42$.
- 20 11. The method of embodiment 4, wherein the Cu-Zn-Si alloy comprises in weight percent:
- $2.5 \leq \text{Si} \leq 3.7$, such as from $2.7 \leq \text{Si} \leq 3.5$; and
- where $37 \leq Q \leq 480$, preferably $40 \leq Q \leq 46$.
12. The method of any one of embodiments 2 to 11, wherein the Cu-Zn-Si alloy has a tensile strength as determined in accordance with ISO 6892-1:2009 of 300 MPa or more,
- 25 preferably 350 MPa or more, even more preferably 380 MPa or more, even more preferably 400 MPa or more, such as 450 MPa or more.
13. The method of any one of embodiments 2 to 12, wherein the Cu-Zn-Si alloy has an elongation of 25% or more as determined in accordance with ISO 6892-1:2009.

14. The method of any one of embodiments 2 to 13, wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni.
15. The method of any one of embodiments 2 to 14, wherein the Cu-Zn-Si alloy comprises up to 0.2 wt% Al.
- 5 16. The method of any one of embodiments 2 to 15, wherein the Cu-Zn-Si alloy comprises up to 0.03 wt% P.
17. The method of any one of embodiments 2 to 16, wherein the Cu-Zn-Si alloy is free of As, Sb.
- 10 18. A Cu-Zn-Si alloy comprising, consisting essentially of, or **consisting of** the following components in weight percent:
- $11.0 \leq \text{Zn} \leq 13.0$;
- $2.5 \leq \text{Si} \leq 3.7$;
- $0.1 \leq \text{Fe} \leq 0.5$;
- 15 $0.1 \leq \text{Mn} \leq 0.2$, e.g. $0.1 \leq \text{Mn} \leq 0.15$, preferably in the range: $0.10 \leq \text{Mn} \leq 0.14$;
- wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q,
- where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,
- wherein $36 \leq Q \leq 48$;
- 20 wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni;
- wherein the Cu-Zn-Si alloy comprises no more than 0.2 wt% Al;
- wherein the Cu-Zn-Si alloy comprises no more than 0.03 wt% P;
- wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less, wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and
- 25 wherein the balance is copper, for example, $82.0 \leq \text{Cu} \leq 86.3$, suitably $82.0 \leq \text{Cu} \leq 86.0$, such as $82.0 \leq \text{Cu} \leq 85.8$, preferably $82.0 \leq \text{Cu} \leq 85.0$, for example $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq 84.5$, such as $83.0 \leq \text{Cu} \leq 84.5$;
- said Cu-Zn-Si alloy having a tensile strength as determined in accordance with ISO 6892-1:2009 of 300 MPa or more; preferably 400 MPa or more, and

said alloy having an elongation at fracture of 25% or more, preferably 30% or more, more preferably 40% or more as determined in accordance with ISO6892-1:2009.

19. The Cu-Zn-Si alloy according to claim 18, wherein the Cu-Zn-Si alloy comprises in weight percent:

$$2.5 \leq \text{Si} \leq 3.5.$$

20. The Cu-Zn-Si alloy according to claim 19, wherein $2.5 \leq \text{Si} \leq 3.2$; and where $36 \leq Q \leq 47$, preferably $38 \leq Q \leq 45$, such as from $38 \leq Q \leq 42$.

21. The Cu-Zn-Si alloy according to claim 19, wherein $2.7 \leq \text{Si} \leq 3.5$; and where $37 \leq Q \leq 48$, preferably $40 \leq Q \leq 46$, such as from $40 \leq Q \leq 44$.

22. The Cu-Zn-Si alloy according to any one of embodiments 18 to 21, wherein $11.5 \leq \text{Zn} \leq 13.0$, such as $12.0 \leq \text{Zn} \leq 13.0$.

23. The Cu-Zn-Si alloy according to any one of embodiments 18 to 22, wherein said Cu-Zn-Si alloy is free of As and/or Sb.

24. Components for drinking-water pipes, namely valves and fittings for same, manufactured from a Cu-Zn-Si alloy comprising, consisting essentially of or consisting of the following in weight percent:
 $11.0 \leq \text{Zn} \leq 13.0$;
 $2.5 \leq \text{Si} \leq 3.7$;
 $0.1 \leq \text{Fe} \leq 0.5$;
 $0.1 \leq \text{Mn} \leq 0.2$ e.g. $0.1 \leq \text{Mn} \leq 0.15$, preferably $0.10 \leq \text{Mn} \leq 0.14$;
wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q,
where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,
wherein $36 \leq Q \leq 48$;
wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni;
wherein the Cu-Zn-Si alloy comprises no more than 0.2 wt% Al;
wherein the Cu-Zn-Si alloy comprises no more than 0.03 wt% P;
wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less, wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and

wherein the balance is copper, for example, $82.0 \leq \text{Cu} \leq 86.3$, suitably $82.0 \leq \text{Cu} \leq 86.0$, such as $82.0 \leq \text{Cu} \leq 85.8$, preferably $82.0 \leq \text{Cu} \leq 85.0$, for example $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq 84.5$, such as $83.0 \leq \text{Cu} \leq 84.5$;

said Cu-Zn-Si alloy having a tensile strength as determined in accordance with ISO 6892-

5 1:2009 of 300 MPa or more; and

said alloy having an elongation at fracture of 25% or more, preferably 30% or more, more preferably 40% or more as determined in accordance with ISO 6892-1:2009.

25. Components for drinking-water pipes according to embodiment 24, wherein said
10 components are manufactured from the Cu-Zn-Si alloy according to any one of claims 2 to 6.

26. Components for drinking-water pipes according to embodiment 24 or 25, wherein said alloy has a true solid state density in the range of from 8.0 kg/m^3 to 8.29 kg/m^3 , preferably from 8.0 to 8.28 kg/m^3 , suitably from 8.18 to 8.28 kg/m^3 .

15

27. A method for manufacturing components for drinking-water pipes, namely valves and fittings for same, comprising:

(i) Providing a Cu-Zn-Si alloy comprising, consisting essentially of, or consisting of the following in weight percent:

20 $11.0 \leq \text{Zn} \leq 13.0$;

$2.5 \leq \text{Si} \leq 3.7$;

$0.1 \leq \text{Fe} \leq 0.5$;

$0.1 \leq \text{Mn} \leq 0.2$, e.g. $0.1 \leq \text{Mn} \leq 0.15$, preferably $0.1 \leq \text{Mn} \leq 0.14$;

wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q,

25 ([Si]) amounts to a combined weight percentage Q,

where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,

wherein $36 \leq Q \leq 48$;

wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni;

wherein the Cu-Zn-Si alloy comprises no more than 0.2 wt% Al;

30 wherein the Cu-Zn-Si alloy comprises no more than 0.03 wt% P;

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less, wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and

wherein the balance is copper, for example, $82.0 \leq \text{Cu} \leq 86.3$, suitably $82.0 \leq \text{Cu} \leq 86.0$, such as $82.0 \leq \text{Cu} \leq 85.8$, preferably $82.0 \leq \text{Cu} \leq 85.0$, for example $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq 84.5$, such as $83.0 \leq \text{Cu} \leq 84.5$;

35

said Cu-Zn-Si alloy having a tensile strength as determined in accordance with ISO 6892-

1:2009 of 300 MPa or more; and

said alloy having an elongation at fracture of 25% or more, preferably 30% or more, more preferably 40% or more as determined in accordance with ISO6892-1:2009; and

(ii) Processing said alloy to form said components.

5 28. The method of embodiment 27, wherein step (ii) includes continuous casting said alloy, and/or wherein step (ii) includes one or more metal forming steps.

29. The method of embodiment 27, wherein step (ii) includes gravity casting said alloy, for example sand casting or die casting said alloy.

10

30. The method of embodiment 27, wherein step (ii) includes one or more metal forming steps, for example forging or rolling said alloy.

15 31. The method of any one of embodiments 27 to 30, wherein step (ii) further includes one or more machining steps.

32. The method of any one of embodiments 27 to 31, wherein the Cu-Zn-Si alloy has a tensile strength as determined in accordance with ISO 6892-1:2009 of 350 MPa or more, preferably 380 MPa or more, even more preferably 400 MPa or more, such as 450 MPa or
20 more.

33. The method of any one of claims 27 to 32, wherein the Cu-Zn-Si alloy has a true solid state density in the range of from 8.0 kg/m³ to 8.29 kg/m³, preferably from 8.0 to 8.28 kg/m³, suitably from 8.18 to 8.28 kg/m³, when determined in accordance with BS ISO 12154.

25

EXAMPLES

Example 1

[0074] A rod was continuously cast from a Cu-Zn-Si alloy of the present invention comprising:

$$81.0 \leq \text{Cu} \leq 86.5$$

5 $11.5 \leq \text{Zn} \leq 13.0$

$$2.9 \leq \text{Si} \leq 3.4$$

$$0.1 \leq \text{Fe} \leq 0.5$$

$$0.1 \leq \text{Mn} \leq 0.2;$$

$$\text{wherein } 42 \leq Q \leq 47;$$

10 wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,

wherein said impurities contain no more than 0.06 wt% Sn, and no more than 0.06 wt% Pb.

The composition of Example 1 contained $0.010 \leq \text{Ni} \leq 0.025$

The composition of Example 1 was free of Bi, Ag, Te and As.

15 The amount of copper was in the range of from 82.0 to 85.0 wt% based on the total weight of the alloy.

[0075] Ingots having an alloy composition as specified above, were loaded into a furnace capable of smelting and casting. The alloy was heated to a temperature in the range of from 1000 to 1200°C, and the smelt is cast through graphite dies with copper coolers. The liquid metal is cooled and drawn as a continuous rod or tube. The tubes are cut to size and are conveyed to a
20 stamping station and/or a machining station.

[0076] For a stamping process, the continuously cast rod is cut into billets of a particular size (size varies depending on the amount of material required to manufacture the end component part). The billets may then be heated and forged. After forging the stamp is cooled and trimmed. The stamp may optionally be annealed, for example by heating to a temperature in the range of
25 from 700 to 900°C. The stamp is cleaned and then sent to a machining station.

[0077] The continuously cast Cu-Zn-Si alloy of Example 1 was employed to manufacture components for drinking water pipes in a process involving stamping and machining steps.

[0078] The tensile strength and elongation of the Cu-Zn-Si alloy was assessed in accordance with ISO 6892-1:2009 on a Hounsfield tensometer:

Measurement parameters:

Elongation sensor type: extensometer

Measuring length of extensometer (Le): 50 mm

Force measuring range: 50 kN

Environmental monitoring:

Humidity: 50,0 %

Temperature: 22,0 °C

Sample data:

Sample initial dimensions - D0: 9,50 mm S0: 70,88 mm²

Initial measuring length (L0): 50,00 mm

Parallel part length (Lc): 55,00 mm

Sample results:

Tensile strength Rm: 488,2 MPa

% Elongation at fracture (Agt): 51,214 %

[0079] A cross section of the continuously cast rod of Example 1 is shown in Figure 1.

5 **[0080]** Figure 2 shows a magnified image of Figure 1. Captured using 5XJP-6A Metallurgical Microscope20x lens Microscope camera DLT-Cam PRO with samples from a Ø26 rod in an Acid mixture: HCl (20%) : H₂NO₃ (20%): H₂SO₄ (20%)1 : 2.

[0081] Figure 3 shows the ends of the continuously cast Cu-Zn-Si alloy rod of example 1 having been extended to break in the extensometer.

Example 2

10 **[0082]** A rod was continuously cast from a Cu-Zn-Si alloy of the present invention having the following composition:

$$82 \leq \text{Cu} \leq 86.5$$

$$12.0 \leq \text{Zn} \leq 13.0$$

$$2.7 \leq \text{Si} \leq 3.1$$

$$0.1 \leq \text{Fe} \leq 0.5$$

5 $0.1 \leq \text{Mn} \leq 0.2$;

wherein $38 \leq Q \leq 44$;

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,

wherein said impurities contain no more than 0.06 wt% Sn, and no more than 0.05 wt% Pb.

The composition of Example 2 contained $0.010 \leq \text{Ni} \leq 0.025$.

10 The composition of Example 2 was free of Bi, Ag, Te and As.

The amount of copper was in the range of from 82.0 to 85.0 wt% based on the total weight of the alloy.

[0083] The continuously cast rod was processed as described in Example 1.

15 **[0084]** The tensile strength and elongation of a continuously cast Cu-Zn-Si alloy from Example 2 was assessed in accordance with ISO 6892-1:2009 on a Hounsfield tensometer:

Measurement parameters:

Elongation sensor type: extensometer

Measuring length of the extensometer (Le): 50 mm

Force measuring range: 50 kN

20 **Environmental monitoring:**

Humidity: 50,0 %

Temperature: 20,0 °C

Sample Data

Sample initial dimensions - D0: 9,48 mm S0: 70,58 mm²

Initial measuring length (L₀): 50,00 mm

Parallel part length (L_c): 55,00 mm

Sample results:

Tensile strength (R_m): 454,0 MPa

5 % Elongation at fracture (A_{gt}): 43,036 %

[0085] Figure 4 shows a cross section of a continuously cast rod according to Example 2.

[0086] It was surprisingly found that the Cu-Zn-Si alloy of the invention when continuously cast, had significantly superior tensile strengths and elongation at fracture properties in comparison to prior art continuous castings. For example, continuous castings had a tensile strength of 380 MPa or more, preferably 400 MPa or more, even more preferably 450 MPa or more as determined in accordance with ISO 6892-1:2009. In addition, continuous castings of the present invention had a percentage elongation at fracture of 25% or more, preferably 30% or more, even more preferably 40% or more as determined in accordance with ISO 6892-1:2009. For example, continuous castings had a percentage elongation at fracture in the range of 25% to 65%, such as from 35% to 60% as determined in accordance with ISO 6892-1:2009. Suitably, the Cu-Zn-Si alloy of the present invention and continuous castings made therefrom, have a tensile strength of 380 MPa or more, and an elongation at fracture in the range of from 25% to 65%, preferably, the tensile strength is in the range of from 380 MPa to 650 MPa, preferably from 400 MPa to 600, such as from 450 MPa to 600 MPa, and the elongation at fracture is 25% to 65%, such as 35% to 60% as determined in accordance with ISO 6892-1:2009.

Example 3

[0087] A rod was gravity die cast from a Cu-Zn-Si alloy of the present invention having the following composition:

$82.5 \leq \text{Cu} \leq 84.5$

25 $11.5 \leq \text{Zn} \leq 12.3$

$3.3 \leq \text{Si} \leq 3.5$

$0.1 \leq \text{Fe} \leq 0.5$

$0.1 \leq \text{Mn} \leq 0.2$;

wherein $40 \leq \text{Q} \leq 44$;

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,

wherein said impurities contain no more than 0.06 wt% Sn, and no more than 0.06 wt% Pb.

The composition of Example 3 contained $0.010 \leq \text{Ni} \leq 0.025$.

The composition of Example 3 was free of Bi, Ag and As.

5 **[0088]** Ingots having an alloy composition as specified above, were loaded into a furnace capable of smelting and casting. The alloy was heated to a temperature in the range of from 1000 to 1300°C, suitably between 1150 and 1300°C.

10 **[0089]** In this step chemical composition may be monitored and controlled to ensure the composition is maintained. For example should some elements (e.g. Zn and P) evaporate or go to slag, they must be replaced to keep the required composition of the present invention. The smelted metal is transported and poured into a holding furnace, and subsequently cast into a die casting. The liquid metal is cooled in the die (for example with air cooling or water cooling) and once solidified the die is opened and the rod is released. Advantageously, the Cu-Zn-Si alloy of the present invention has enhanced tensile strength and elongation properties in comparison to
15 prior art Cu-Zn-Si alloys. The enhanced properties increase the processing ease of the alloy.

[0090] The properties of the die casting were assessed in accordance with ISO 6892-1:2009 on a Hounsfield tensometer, as outlined above for Examples 1 and 2.

[0091] The casting had a tensile strength of >380 MPa, and an elongation at fracture of >25% as determined in accordance with ISO 6892-1:2009.

20 **[0092]** Advantageously, the Cu-Zn-Si alloys of the examples had a manganese content in the range: $0.10 \leq \text{Mn} \leq 0.14$; the alloys of the invention advantageously have even further enhanced elongation when the amount of manganese is in this preferred range.

25 **[0093]** Advantageously, the true solid state density of the Cu-Zn-Si alloys of the examples described herein was in the range of from 8.18 to 8.28 Kg/m³ as measured in accordance with BS ISO 12154. BS ISO 12154 defines true solid state density as the ratio of the sample mass to the volume of the compact solid skeleton of the sample which excludes the volume of open and closed pores or internal voids and also interparticle voids as in the case of granulated or highly dispersed samples.

Comparative Examples

30 **[0094]** A rod was cast from a Cu-Zn-Si alloy having the following compositions:

CE1	CE2	CE3
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Element	wt%	Element	wt%	Element	wt%
Cu	82.060	Cu	85.620	Cu	82.730
Sn	0.038	Sn	0.043	Sn	0.082
Zn	14.137	Zn	9.792	Zn	12.353
Pb	0.136	Pb	0.073	Pb	0.095
Ni	0.012	Ni	0.016	Ni	0.015
Sb	0.026	Sb	0.066	Sb	0.058
Al.	0.008	Al.	0.007	Al.	0.005
As	0.006	As	0.006	As	0.001
Fe	0.118	Fe	0.124	Fe	0.269
Mn	0.092	Mn	0.092	Mn	0.153
P	0.002	P	0.000	P	0.002
S	0.004	S	0.006	S	0.003
Si	3.359	Si	4.157	Si	4.227
Bi	0.001	Bi	0.000	Bi	0.006
Ag	0.000	Ag	0.000	Ag	0.000
Q (wt%)	47.7	Q (wt%)	51.36	Q (wt%)	54.6
Tensile strength (MPa)	134.1	Tensile strength (MPa)	322.7	Tensile strength (MPa)	391.9
%Elongation at fracture	6.05	%Elongation at fracture	-	%Elongation at fracture	7.28

[0095] CE1 comprises >13 wt% Zn, and despite containing 0.136 wt% Pb, has low tensile strength and low.

[0096] CE2 comprises < 11 wt% Zn, > 4.1 wt% Si and had an excellent tensile strength. However, the alloy was very brittle (see Figure 7). Hence, suitable the alloy of CE2 did not have suitable elongation properties.

[0097] CE3 comprises >4.1 wt% Si and has a Q of >52 wt%. The tensile strength was excellent however, the elongation was not suitable.

Comparative Example 4 (CE4)

[0098] A rod was gravity die cast from a Cu-Zn-Si alloy of the present invention having the following composition:

$$82 \leq \text{Cu} \leq 86.5$$

$$11.5 \leq \text{Zn} \leq 12.3$$

$$3.6 \leq \text{Si} \leq 4.1$$

$$0.1 \leq \text{Fe} \leq 0.5$$

$$0.1 \leq \text{Mn} \leq 0.2;$$

$$\text{wherein } 48 \leq Q \leq 51;$$

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,

5 wherein said impurities contain no more than 0.06 wt% Sn, and no more than 0.06 wt% Pb.

The composition of Example 3 contained $0.010 \leq \text{Ni} \leq 0.025$.

The composition of Example 3 was free of Bi, Ag and As.

[0099] The properties of the die casting were assessed in accordance with ISO 6892-1:2009 on a Hounsfield tensometer, as outlined above for Examples 1 and 2.

10 **[00100]** The Cu-Zn-Si alloy of comparative example 4 had a tensile strength of 363.6 MPa, and an elongation at fracture of 16%. The Cu-Zn-Si alloy of comparative example 4 had a Q of approximately 50.

[00101] Figure 5 shows a cross section of the rod cast in Comparative Example 4. Advantageously, the grain is uniform/homogenous, however, the elongation of the rod cast in comparative example 4, was 16%. Figure 6 shows the ends of the die cast Cu-Zn-Si alloy rod of comparative example 4 having been extended to break in the extensometer.

15 **[00102]** Thus while the alloy of comparative example 4 had excellent tensile strength, the elongation at fracture was less than 25%. Advantageously, Cu-Zn-Si alloys according to the invention which have Q in the range: $36 \leq Q \leq 48$, and for gravity cast Cu-Zn-Si alloys of the invention preferably $40 \leq Q \leq 46$, and for continuous cast Cu-Zn-Si alloys of the invention preferably $38 \leq Q \leq 45$, have elongation at fracture of 25% or more as determined in accordance with ISO6892-1:2009.

Example 4

25 **[00103]** A rod was continuously cast from a Cu-Zn-Si alloy of the present invention as described in Examples 1 and 2, the Cu-Zn-Si alloy of example 4 had the following composition:

$$82.5 \leq \text{Cu} \leq 84.5$$

$$12.5 \leq \text{Zn} \leq 13.0$$

$$2.6 \leq \text{Si} \leq 2.9$$

$0.1 \leq \text{Fe} \leq 0.5$

$0.1 \leq \text{Mn} \leq 0.15$;

wherein $38.5 \leq Q \leq 42$;

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less,

5 wherein said impurities contain no more than 0.06 wt% Sn, and no more than 0.06 wt% Pb.

The composition of Example 4 contained $0.010 \leq \text{Ni} \leq 0.025$

The composition of Example 1 was free of Bi, Ag, Te and As.

10 **[00104]** A comparison of the mechanical properties of a Cu-Zn-Si alloy of the present invention versus (Example 4) and C87800 is provided in Table 1:

Table 1: Mechanical Properties			
	Tensile strength	Elongation at break	Hardness Brinell
C87800	460 Mpa	25%	134
Cu-Zn-Si alloy (Example 4)	450 Mpa	40%	107

[00105] Advantageously, the Cu-Zn-Si alloy of the present invention has greater ductility, and in particular has a greater elongation at fracture as determined in accordance with ISO6892-1:2009.

15 **[00106]** A comparison of the physical properties of a Cu-Zn-Si of the present invention and C87800 is provided in Table 2:

Table 2: Physical Properties					
	Melting Point - Liquidus °C	Melting Point - Solidus °C	Thermal Conductivity [W m ⁻¹ °C ⁻¹]	Specific Heat [J kg ⁻¹ °C ⁻¹]	Density [kg m ⁻³]
C87800	915	821	27.67	398.86	8,304
Cu-Zn-Si alloy**	961	831	43.45	376.80	8,250

20 **[00107]** Advantageously, the alloy of the present invention has a lower density than the prior art alloy. Thus, the alloy of the present invention is a lighter weight alloy, but has the similar tensile strength performance, and greater elongation properties than the prior art alloy. Moreover, being a lighter material, the alloy of the present invention, will have less distribution cost, per metre cubed, and from an environmental standpoint, will be more economical to transport per metre. It

is particularly desirable that the alloy of the present invention has a true solid state density in the range of from 8.0 kg/m³ to 8.29 kg/m³, preferably from 8.0 to 8.28 kg/m³, suitably from 8.18 to 8.28 kg/m³. In contrast the alloys of the comparative examples have a true solid state density of 8.30 kg/m³ or higher.

5 **[00108]** A comparison of the performance of Cu-Zn-Si of the present invention and C87800 in various fabrication processes is provided in Table 3:

Table 3: Fabrication processes			
	ASTM Temper Code	C87800	Cu-Zn-Si alloy**
Sand mould cast	M01	No	Yes
Die cast	M04	Yes	Yes
Permanent mould cast	M05	Yes	Yes
Continuous cast	M07	No	Yes
Hot forged and air cooled	M10	No	Yes
Hot forged and quenched	M11	No	Yes

10 **[00109]** Advantageously , the alloy of the present invention may be processed in each of the fabrication processes described above, whereas the prior art C87800 alloy is not suitable for sand mould casting, continuous casting, hot forged and air cooled processes, or hot forged and quenched processes.

15 **[00110]** The words “comprises/comprising” and the words “having/including” when used herein with reference to the present invention are used to specify the presence of stated features, integers, steps or components but do not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

20 **[00111]** It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub-combination.

Claims

1. A Cu-Zn-Si alloy comprising, consisting essentially of, or **consisting of** the following components in weight percent:

$11.0 \leq \text{Zn} \leq 13.0$;

5 $2.5 \leq \text{Si} \leq 3.7$;

$0.1 \leq \text{Fe} \leq 0.5$;

$0.1 \leq \text{Mn} \leq 0.2$;

wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q,

10 where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,

wherein $36 \leq Q \leq 48$;

wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni;

wherein the Cu-Zn-Si alloy comprises no more than 0.2 wt% Al;

wherein the Cu-Zn-Si alloy comprises no more than 0.03 wt% P;

15 wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less, wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and

wherein the balance is copper, for example, $82.0 \leq \text{Cu} \leq 86.3$, suitably $82.0 \leq \text{Cu} \leq 86.0$, such as $82.0 \leq \text{Cu} \leq 85.8$, preferably $82.0 \leq \text{Cu} \leq 85.0$, for example $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq 84.5$, such as $83.0 \leq \text{Cu} \leq 84.5$;

20 said Cu-Zn-Si alloy having a tensile strength as determined in accordance with ISO 6892-1:2009 of 300 MPa or more; preferably 400 MPa or more, and

said alloy having an elongation at fracture of 25% or more, preferably 30% or more, more preferably 40% or more as determined in accordance with ISO 6892-1:2009.

25 2. The Cu-Zn-Si alloy according to claim 1, wherein the Cu-Zn-Si alloy comprises in weight percent:

$2.5 \leq \text{Si} \leq 3.5$.

3. The Cu-Zn-Si alloy according to claim 2, wherein $2.5 \leq \text{Si} \leq 3.2$; and where $36 \leq Q \leq 47$, preferably $38 \leq Q \leq 45$, such as from $38 \leq Q \leq 42$.
- 5 4. The Cu-Zn-Si alloy according to claim 2, wherein $2.7 \leq \text{Si} \leq 3.5$; and where $37 \leq Q \leq 48$, preferably $40 \leq Q \leq 46$, such as from $40 \leq Q \leq 44$.
5. The Cu-Zn-Si alloy according to any preceding claim, wherein $11.5 \leq \text{Zn} \leq 13.0$, such as $12.0 \leq \text{Zn} \leq 13.0$.
- 10 6. The Cu-Zn-Si alloy according to any preceding claim, wherein said Cu-Zn-Si alloy is free of As and/or Sb.
7. Components for drinking-water pipes, namely valves and fittings for same, manufactured from a Cu-Zn-Si alloy comprising, consisting essentially of or consisting of the following in weight percent:
- 15 $11.0 \leq \text{Zn} \leq 13.0$;
 $2.5 \leq \text{Si} \leq 3.7$;
 $0.1 \leq \text{Fe} \leq 0.5$;
 $0.1 \leq \text{Mn} \leq 0.2$;
- 20 wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q,
where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,
wherein $36 \leq Q \leq 48$;
- 25 wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni;
wherein the Cu-Zn-Si alloy comprises no more than 0.2 wt% Al;
wherein the Cu-Zn-Si alloy comprises no more than 0.03 wt% P;
wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less, wherein said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and
- 30 wherein the balance is copper, for example, $82.0 \leq \text{Cu} \leq 86.3$, suitably $82.0 \leq \text{Cu} \leq 86.0$, such as $82.0 \leq \text{Cu} \leq 85.8$, preferably $82.0 \leq \text{Cu} \leq 85.0$, for example $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq 84.5$, such as $83.0 \leq \text{Cu} \leq 84.5$;
- said Cu-Zn-Si alloy having a tensile strength as determined in accordance with ISO 6892-1:2009 of 300 MPa or more; and
- 35 said alloy having an elongation at fracture of 25% or more, preferably 30% or more, more preferably 40% or more as determined in accordance with ISO 6892-1:2009.
8. Components for drinking-water pipes according to claim 7, wherein said components are manufactured from the Cu-Zn-Si alloy according to any one of claims 2 to 6.

9. Components for drinking-water pipes according to any preceding claim, wherein said alloy has a density in the range of from 8.0 kg/m³ to 8.29 kg/m³, preferably from 8.0 to 8.28 kg/m³, suitably from 8.18 to 8.28 kg/m³.

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10. A method for manufacturing components for drinking-water pipes, namely valves and fittings for same, comprising:

(i) Providing a Cu-Zn-Si alloy comprising, consisting essentially of, or consisting of the following in weight percent:

10 $11.0 \leq \text{Zn} \leq 13.0$; $2.5 \leq \text{Si} \leq 3.7$; $0.1 \leq \text{Fe} \leq 0.5$; $0.1 \leq \text{Mn} \leq 0.2$;

wherein the sum of the weight percentage of Zn ([Zn]) and ten times the weight percentage of Si ([Si]) amounts to a combined weight percentage Q,

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where $Q = [\text{Zn}] + (10 \times [\text{Si}])$,

wherein $36 \leq Q \leq 48$;

wherein the Cu-Zn-Si alloy comprises in weight percent no more than 0.05% Ni;

wherein the Cu-Zn-Si alloy comprises no more than 0.2 wt% Al;

20

wherein the Cu-Zn-Si alloy comprises no more than 0.03 wt% P;

wherein the alloy includes unavoidable impurities in an amount of 0.53 wt% or less, wherein

said impurities contain no more than 0.2 wt% Sn, and no more than 0.06 wt% Pb; and

wherein the balance is copper, for example, $82.0 \leq \text{Cu} \leq 86.3$, suitably $82.0 \leq \text{Cu} \leq 86.0$, such as $82.0 \leq \text{Cu} \leq 85.8$, preferably $82.0 \leq \text{Cu} \leq 85.0$, for example $82.2 \leq \text{Cu} \leq 85.0$, or $82.5 \leq \text{Cu} \leq$

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84.5, such as $83.0 \leq \text{Cu} \leq 84.5$;

said Cu-Zn-Si alloy having a tensile strength as determined in accordance with ISO 6892-1:2009 of 300 MPa or more; and

said alloy having an elongation at fracture of 25% or more, preferably 30% or more, more preferably 40% or more as determined in accordance with ISO 6892-1:2009; and

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(ii) Processing said alloy to form said components.

11. The method of claim 10, wherein step (ii) includes continuous casting said alloy, and/or wherein step (ii) includes one or more metal forming steps.

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12. The method of claim 10, wherein step (ii) includes gravity casting said alloy, for example sand casting or die casting said alloy.

13. The method of claim 10, wherein step (ii) includes one or more metal forming steps, for example forging or rolling said alloy.

5 14. The method of any one of claims 10 to 13, wherein step (ii) further includes one or more machining steps.

15. The method of any one of claims 10 to 14, wherein the Cu-Zn-Si alloy has a tensile strength as determined in accordance with ISO 6892-1:2009 of 350 MPa or more, preferably
10 380 MPa or more, even more preferably 400 MPa or more, such as 450 MPa or more.

16. The method of any one of claims 10 to 15, wherein the Cu-Zn-Si alloy has a density in the range of from 8.0 kg/m³ to 8.29 kg/m³, preferably from 8.0 to 8.28 kg/m³, suitably from 8.18 to 8.28 kg/m³.

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