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(54) **LOW COST HIGH DUCTILITY CAST ALUMINUM ALLOY**

(57) A secondary (recycled) aluminum alloy for casting into a structural component, such as a vehicle component, is provided. The aluminum alloy includes at least 80 wt. % aluminum, 0.1 wt. % to 0.6 wt. % copper, 6.0 wt. % to 8.0 wt. % silicon, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.12 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy.

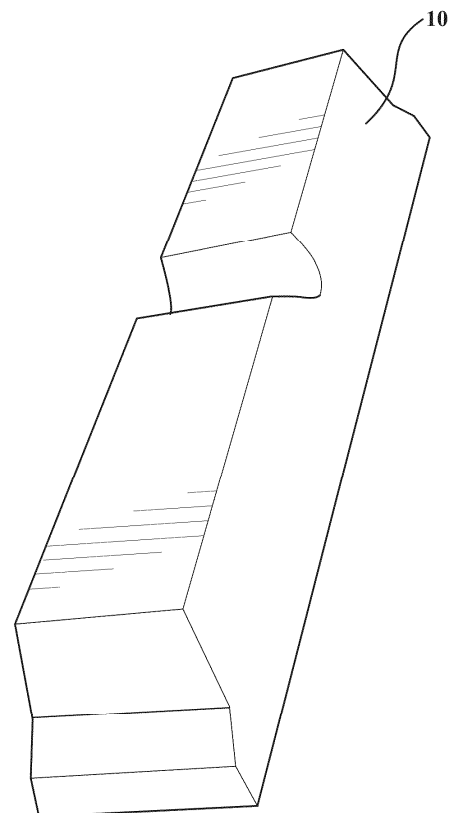


FIG. 1

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Description

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This U.S. Non-Provisional Patent Application claims the benefit of and priority to U.S. Provisional Patent Application Serial No. 63/741,680 filed January 3, 2025, entitled "Low Cost High Ductility Cast Aluminum Alloy," the contents of which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The invention relates generally to a secondary aluminum alloy for casting, a method of forming the aluminum alloy, a cast component formed of the cast aluminum alloy, and a method of manufacturing the cast component.

2. Related Art

[0003] Casting of aluminum alloys is oftentimes used in the automotive industry to form lightweight components, including complex structural, body-in-white, suspension, and chassis components. There are many types of known casting processes, for example, high pressure die casting, low pressure casting, and squeeze casting. The die is typically formed of a hardened tool steel. Although the casting equipment is expensive, the cost per component formed is relatively low, which makes the process suitable for high volume production.

[0004] However, improvements to the casting process and materials used in the casting process are desired. For example, an aluminum alloy capable of forming a component having high ductility, without loss of fluidity or castability, is desired. The aluminum alloy should also be resistant to damage associated with hot cracking, soldering, shrinkage, and corrosion. In addition, although lightweight components are desired, the components should still provide a high strength and toughness.

SUMMARY

[0005] One aspect of the disclosure provides a secondary structural aluminum alloy, comprising at least 80 weight percent (wt. %) aluminum, 0.1 wt. % to 0.6 wt. % copper, 6.0 wt. % to 8.0 wt. % silicon, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.12 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy.

[0006] Another aspect of the invention provides a method of manufacturing a component. The method comprises casting a recycled aluminum alloy, the recycled aluminum alloy including at least 80 weight percent (wt. %) aluminum, 0.1 wt. % to 0.6 wt. % copper, 6.0 wt. % to 8.0 wt. % silicon, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.12 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy.

[0007] A method of manufacturing an aluminum alloy, comprising the steps of: melting a 300 series or 6xxx series recycled aluminum alloy; and adding at least one additional element to the melted aluminum alloy to form an improved aluminum alloy. The at least one additional element is added so that the improved aluminum alloy includes at least 80 weight percent (wt. %) aluminum, 6.0 wt. % to 8.0 wt. % silicon, 0.1 wt. % to 0.6 wt. % copper, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.15 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the improved aluminum alloy.

[0008] The cast aluminum alloy is able to achieve a yield strength of at least 110 MPa, ultimate tensile strength (UTS) of at least 220 MPa, and an elongation of 7 to 20 % (depending on flow length) at F temper. The cast aluminum alloy also has an unexpectedly high level of corrosion resistance.

BRIEF DESCRIPTION OF THE DRAWING

[0009] Other advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing wherein: Figure 1 is a portion of an example component formed of an aluminum alloy according to an embodiment.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0010] One aspect of the invention provides an improved aluminum alloy for casting components 10, such as a lightweight automotive vehicle component, is provided. The aluminum alloy can be referred to as a secondary structural aluminum alloy. As a structural aluminum alloy, the aluminum alloy can be used to form body structural components 10 with good crashworthiness due to high ductility. Examples of components 10 which can be formed of the aluminum alloy include structural, body-in-white, suspension, or chassis components. The aluminum alloy is capable of providing acceptable corrosion resistance, as well as acceptable ductility and elongation, acceptable self-piercing rivet behavior, without hot tearing or loss of fluidity or castability. Unlike a primary aluminum alloy, which is made from an aluminum extraction operation (bauxite) and alloying elements, the secondary aluminum alloy is made using recycled materials, for example recycled 3xx castings and 6xxx wrought alloys.

[0011] The improved aluminum alloy is aluminum-based, and thus typically includes aluminum in an amount of at least 80 weight percent (wt. %), based on the total weight of the aluminum alloy. In one embodiment, the aluminum alloy is formed by modifying a recycled 300 series or recycled 6xxx series aluminum alloy. A specific example of the recycled 300 series aluminum alloy is a 356.2 aluminum alloy obtained from recycled road wheels. The 356.2 aluminum alloy includes 91.3 to 93.2 wt. % aluminum, not greater than 0.10 wt. % copper, 0.13-0.25 wt. % iron, 0.30 to 0.45 wt. % magnesium, not greater than 0.05 wt. % manganese, 6.5 to 7.5 wt. % silicon, not greater than 0.20 wt. % titanium, not greater than 0.05 wt. % zinc, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the improved aluminum alloy. However, other types of recycled aluminum alloys, such as 6xxx series scraps, could be modified to form the improved aluminum alloy.

[0012] Alloying elements are present in the improved aluminum alloy to achieve acceptable elongation and ductility, and/or to achieve the desired strength and toughness. For example, silicon (Si), magnesium (Mg), manganese (Mn), and/or iron (Fe) can be added to control ductility, castability, strength, ductility, and/or toughness. In particular, the manganese can be used to prevent die sticking, and the magnesium can be used to form Mg_2Si for strengthening. The aluminum alloy can also include copper (Cu) and zinc (Zn) to increase strength, preferably without negatively impacting corrosion resistance. The zinc is also used as a solid solution strengthener and to improve machinability. The additional alloying elements can provide other metallurgical effects as well, such as improved resistance to hot cracking, soldering, shrinkage, and corrosion. For example, special properties or other metallurgical effects can be achieved by titanium (Ti). Strontium (Sr) can also be added to modify properties that occur due to the silicon.

[0013] According to one example embodiment, in addition to at least 80 wt. % aluminum, the aluminum alloy includes 0.1 wt. % to 0.3 wt. % copper, 6.0 wt. % to 8.0 wt. % silicon, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.12 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy. The other elements can include any element besides those listed above, for example impurities which are not intentionally added to the composition.

[0014] The manganese and iron can form an intermetallic phase that prevents the alloy from attacking tool steel of a die, which is typically caused by low iron content. When the aluminum alloy is cast, the cast aluminum alloy has a yield strength of at least 110 MPa, ultimate tensile strength (UTS) of at least 220 MPa, and an elongation 7 to 20 % (depending on flow length) at F temper.

[0015] According to other example embodiments, the aluminum alloy consists of, or consists essentially of, at least 80 wt. % aluminum, 0.1 wt. % to 0.3 wt. % copper, 6.0 wt. % to 8.0 wt. % silicon, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.12 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy.

[0016] According to preferred example embodiments, the aluminum alloy includes at least 80 wt. % aluminum, not greater than 0.30 wt. % copper, 7.1 wt. % to 7.5 wt. % silicon, 0.10 wt. % to 0.18 wt. % magnesium, not greater than 0.5 wt. % zinc, 0.15 wt. % to 0.30 wt. % iron, 0.4 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy. The combined content of iron and manganese is around 0.8 wt. %, for example 0.7 wt. % to 0.9 wt. %, based on the total weight of the aluminum alloy.

[0017] According to another preferred embodiment, the aluminum alloy consists of, or consists essentially of, at least 80 wt. % aluminum, not greater than 0.30 wt. % copper, 7.1 wt. % to 7.5 wt. % silicon, 0.10 wt. % to 0.18 wt. % magnesium, not greater than 0.5 wt. % zinc, 0.15 wt. % to 0.30 wt. % iron, 0.4 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy. The combined content of iron and manganese is around 0.8 wt. %, for example 0.7 wt. % to 0.9 wt. %, based on the total weight of the aluminum alloy.

[0018] According to another example embodiment, the aluminum alloy includes not greater than 0.28 wt. % copper and

not greater than 0.25 wt. % iron, based on the total weight of the aluminum alloy.

[0019] Another aspect of the invention provides a method of manufacturing the aluminum alloy. In one embodiment, the aluminum alloy is formed by modifying a 300 series and/or 6xxx series recycled aluminum alloy. The aluminum alloy is preferable obtained from recycled castings and wrought aluminum. A specific example of the 300 series aluminum alloy is a 356.2 aluminum alloy obtained from recycled road wheels. The 356.2 aluminum alloy includes 91.3 to 93.2 wt. % aluminum, not greater than 0.10 wt. % copper, 0.13 to 0.30 wt. % iron, 0.30 to 0.45 wt. % magnesium, not greater than 0.05 wt. % manganese, 6.5 to 7.5 wt. % silicon, not greater than 0.20 wt. % titanium, not greater than 0.05 wt. % zinc, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the improved aluminum alloy. Manufacturing the improved aluminum alloy from one or more of the recycled materials lowers the raw material cost, as it takes 95% less energy to recycle an aluminum alloy than to create it from primary elements.

[0020] The method of forming the cast component 10 typically begins by melting the recycled cast aluminum, or other base aluminum alloys. The melting step can be conducted by a reverb or induction melter, or another source of heat. Once the base aluminum alloy is melted, the method includes adjusting the content of silicon and/or at least one other element in the melt and mixing the silicon and/or other element(s) with the base aluminum alloy to achieve the final improved alloy composition. The additional alloying elements, discussed above, can be added to the melted mixture to form the improved aluminum alloy. Alternatively, the additional alloying elements could be present in the wrought aluminum or other base aluminum alloy. Once all of the elements are mixed together, the aluminum alloy is ready for casting.

[0021] The method then includes casting the aluminum alloy which includes at least 80 weight percent (wt. %) aluminum, 0.1 wt. % to 0.6 wt. % copper, 6.0 wt. % to 8.0 wt. % silicon, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.12 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy. After the casting step, the cast aluminum alloy has a yield strength of at least 110 MPa, ultimate tensile strength (UTS) of at least 220 MPa, and an elongation of 7 to 20 % (depending on flow length) at F temper.

[0022] The cast component 10 formed from the casting step can be, for example, a component for use in a vehicle. Any casting process used to form components from an aluminum-based material can be used with the improved aluminum alloy, for example high pressure die casting, low pressure casting, or squeeze casting. In one example embodiment, the casting process is a high pressure die casting process, which typically includes forcing the molten aluminum alloy into an unheated die or mold cavity under pressure. The die is typically formed from hardened tool steel. The molten aluminum is formed to a solid component 10 having the shape of the mold, which can be a complex shape. Many different types of components 10 can be formed by the casting process, for example, a structural, body-in-white, suspension, or chassis component. After the casting process, the method can include an optional heat treating process, paint cure oven exposure or other finishing processes. However, it has been found that a heat treatment process may not be necessary when the component 10 is formed from the improved aluminum alloy, which would provide the advantage of reduced process time and costs.

[0023] As stated above, the component 10 formed from the improved aluminum alloy has a high level of corrosion resistance which was unexpected in view of the prior art. The component 10 formed from the improved aluminum alloy also has acceptable ductility, elongation, resistance to hot cracking, soldering, shrinkage, self-piercing riveting (SPR) behavior, fatigue, bending, strength, and toughness. As discussed above, the cast component 10 formed of the aluminum alloy typically has a yield strength of at least 110 MPa, ultimate tensile strength (UTS) of at least 220 MPa, and an elongation of 7 to 20 % (depending on flow length) at F temper.

[0024] Table 1 includes examples of the improved aluminum alloy according to the invention. It was discovered that the example aluminum alloys according to the invention provide the unexpected improvement in corrosion resistance relative to comparative example alloys.

Table 1

Alloy	Cu	Si	Mg	Zn	Fe	Mn	Ti	Sr	Others	Total Others
Aural 5R-preferred embodiment	0.30 max	7.1-7.5	0.1-0.18	0.5 max	0.12-0.25	0.4-0.6	0.15 max	0.015-0.03	0.05 max	0.15 max
Ex. 1 new Aural 5R	0.1 - 0.6	6.0 - 8.0	0.10 - 0.60	0.10 to 0.50	0.15 - 0.30	0.2 - 0.6	0.15 max	0.015-0.03	0.05 max	0.15 max

[0025] Obviously, many modifications and variations of the present invention are possible in light of the above teachings

and may be practiced otherwise than as specifically described while within the scope of the following claims.

Claims

1. An aluminum alloy, comprising:
at least 80 weight percent (wt. %) aluminum, 0.1 wt. % to 0.6 wt. % copper, 6.0 wt. % to 8.0 wt. % silicon, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.12 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy.
2. The aluminum alloy of claim 1 consisting of at least 80 wt. % aluminum, 0.1 wt. % to 0.6 wt. % copper, 6.0 wt. % to 8.0 wt. % silicon, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.12 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy.
3. The aluminum alloy of claim 1 or 2, wherein the aluminum alloy includes not greater than 0.30 wt. % copper, 7.1 wt. % to 7.5 wt. % silicon, 0.10 wt. % to 0.18 wt. % magnesium, not greater than 0.5 wt. % zinc, 0.15 wt. % to 0.30 wt. % iron, 0.4 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy.
4. The aluminum alloy of one of the preceding claims consisting of at least 80 wt. % aluminum, not greater than 0.30 wt. % copper, 7.1 wt. % to 7.5 wt. % silicon, 0.10 wt. % to 0.18 wt. % magnesium, not greater than 0.5 wt. % zinc, 0.15 wt. % to 0.30 wt. % iron, 0.4 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy.
5. The aluminum alloy of one of the preceding claims, wherein the aluminum alloy is cast and has a yield strength of at least 110 MPa, ultimate tensile strength (UTS) of at least 220 MPa, and an elongation of 7 to 20 % (depending on flow length) in an F temper condition.
6. A method of manufacturing a component, comprising: casting the aluminum alloy according to one of the preceding claims.
7. The method of claim 6, wherein the component formed during the casting step is a component for a vehicle.
8. The method of claim 6 or 7, wherein the casting step includes high pressure die casting, low pressure casting, or squeeze casting.
9. A method of manufacturing a secondary aluminum alloy, comprising the steps of:
melting a recycled 300 series or 6xxx series aluminum alloy; and
adding at least one additional element to the melted aluminum alloy to form the secondary aluminum alloy, the secondary aluminum alloy including: at least 80 weight percent (wt. %) aluminum, 0.1 wt. % to 0.6 wt. % copper, 6.0 wt. % to 8.0 wt. % silicon, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.12 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the secondary aluminum alloy.
10. The method of claim 9 including melting the recycled 300 series aluminum alloy.
11. The method of claim 9 or 10, wherein the recycled 300 series aluminum alloy is obtained from recycled castings, wrought aluminum, or recycled road wheels.
12. The method of one of the preceding claims 9 to 11, wherein the recycled 300 series aluminum alloy includes 91.3 to

93.2 wt. % aluminum, not greater than 0.10 wt. % copper, 0.13 to 0.30 wt. % iron, 0.30 to 0.45 wt. % magnesium, not greater than 0.05 wt. % manganese, 6.5 to 7.5 wt. % silicon, not greater than 0.20 wt. % titanium, not greater than 0.05 wt. % zinc, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the recycled 300 series aluminum alloy.

13. A cast component, comprising:

an aluminum alloy, the aluminum alloy including at least 80 weight percent (wt. %) aluminum, 0.1 wt. % to 0.6 wt. % copper, 6.0 wt. % to 8.0 wt. % silicon, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.12 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy.

14. The cast component of claim 13, wherein the aluminum alloy includes an intermetallic phase formed of the manganese and the iron.

15. The cast component of claim 13 or 14, wherein the aluminum alloy consists of at least 80 wt. % aluminum, 0.1 wt. % to 0.6 wt. % copper, 6.0 wt. % to 8.0 wt. % silicon, 0.10 wt. % to 0.60 wt. % magnesium, 0.10 wt. % to 0.50 wt. % zinc, 0.12 wt. % to 0.30 wt. % iron, 0.2 wt. % to 0.6 wt. % manganese, not greater than 0.15 wt. % titanium, 0.015 wt. % to 0.03 wt. % strontium, other elements each in an amount of not greater than 0.05 wt. %, and other elements in a total amount of not greater than 0.15 wt. %, based on the total weight of the aluminum alloy.

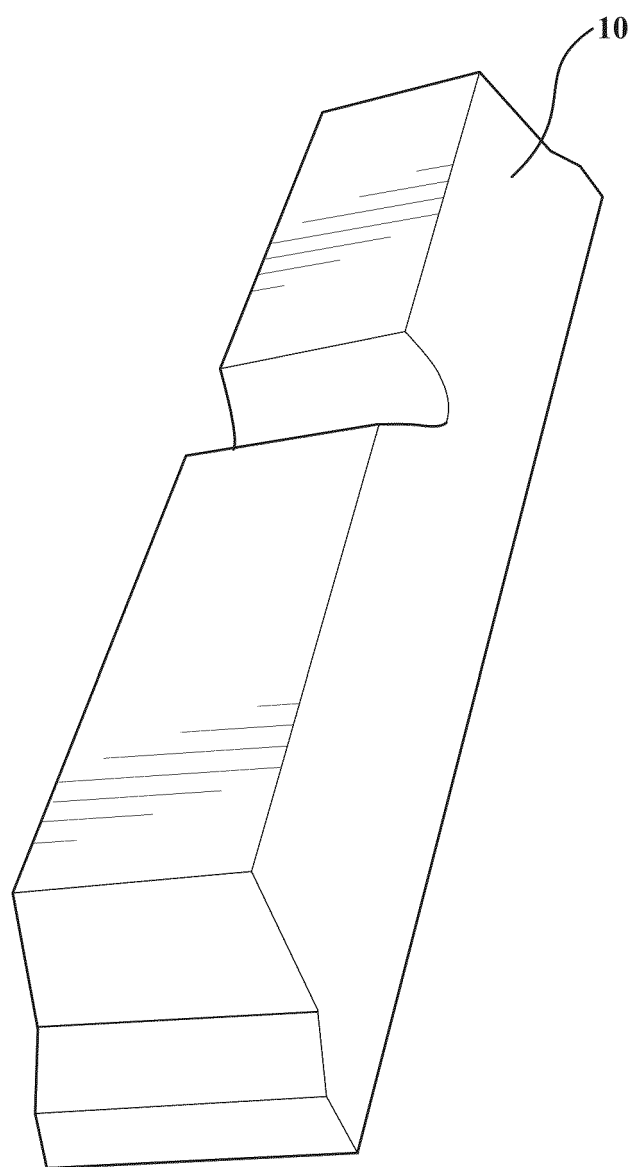


FIG. 1



EUROPEAN SEARCH REPORT

Application Number

EP 26 15 0074

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CN 111 485 144 A (SHANDONG FUZERUI METAL TECH CO LTD) 4 August 2020 (2020-08-04) * paragraphs [0008], [0011], [0019] - [0021] *	1-15	INV. C22C1/02 B22D17/00 B22D21/00 B22D21/04 C22C21/04
A	US 2024/209478 A1 (BEALS RANDY [US] ET AL) 27 June 2024 (2024-06-27) * the whole document *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			C22C B22D
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		28 April 2026	Martinavicius, A
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ON EUROPEAN PATENT APPLICATION NO.

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10	Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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