[0005] Cracking or any defects in the AM component significantly reduces the mechanical properties and performance of the component, such that the advantages gained from AM over conventional manufacturing techniques are lost if these AM components cannot achieve the required performance.

[0006] In the known prior art, special manufacturing techniques are provided for gamma prime superalloys having large compositional ranges, but these compositional ranges do not teach the technology disclosed here in that they contain both cracking and non-cracking superalloy compositions when applied via an AM manufacturing process. In fact, the vast majority of potential alloys within these broad compositional ranges will crack if applied via the additive manufacturing process. By way of example, US 4,226,644 describes manufacturing a superalloy part via a compacting particulate matter technique considered relevant to a broad compositional range. However, a majority of alloys within the disclosed compositional ranges will crack if processed via additive manufacturing. Further, US 2020/0010930 A1 describes manufacturing a superalloy part by a hot plastic working technique considered relevant to a broad compositional range. Again, a majority of alloys within the compositional range will crack if processed via additive manufacturing.

[0007] While a gamma prime strengthened nickel-based superalloy AM is known from, e.g., EP 2886225 B1, EP 2949768 B1 US 10,941,466 B2, US,10,752,978 B2, US 2021/0355564 A1, US 2020/0172998 A1, US 2020/0149145 A1, these alloys contain components in amounts outside of the ranges described in the disclosed embodiments and likewise result in unacceptable cracking in the AM part. Moreover, while other gamma prime strengthened nickel-based superalloys are known, e.g., from US5069873, US9902021B2, US10358701B2, US11459640B2, US20190055627A1, WO2018157228A1, these alloys likewise contain components in amounts outside of the ranges described in the disclosed embodiments, resulting in unacceptable cracking in the AM part.

SUMMARY

[0008] Examples are directed to improving manufacturability of high gamma prime superalloys by reducing crack susceptibility in AM processing.

[0009] Examples are directed to a nickel-based alloy composition for additive manufacturing that includes: 4 – 9 wt.% aluminum; 6 – 14 wt.% cobalt; 4 – 26 wt.% chromium; 2 – 5 wt.% tantalum; 3 – 13 wt.% tungsten; and a balance of nickel.

[0009a] In an aspect of the present disclosure, there is provided a nickel-based alloy composition for additive manufacturing, comprising:
4 – 9 wt.% aluminum;
6 – 15 wt.% cobalt;
4 – 26 wt.% chromium;
2 – 5 wt.% tantalum;
3 – 13 wt.% tungsten; and
balance nickel.

[0010] According to examples, the nickel-based alloy composition can further include at least one of: up to 8 wt.% molybdenum; up to 1 wt.% titanium; and up to 4 wt.% niobium.

[0011] In other examples, the composition of aluminum may be 4.5 – 7.7 wt.%, the composition of cobalt can be 7.7 – 12.9 wt.%, the composition of chromium can be 5 – 23 wt.%, the composition of tantalum may be 2.5 – 4.8 wt.%, and the composition of tungsten can be 3.3 – 11 wt.%. The nickel-based alloy composition may further include at least one of: up to 7.0 wt.% molybdenum; up to 0.9 wt.% titanium; and up to 2.8 wt.% niobium. In other examples, the composition of aluminum can be 5 – 7 wt.%, the composition of cobalt can be 8 – 12 wt.%, the composition of chromium can be 5 – 23 wt.%, the composition of tantalum can be 3 – 4 wt.%, and the composition of tungsten can be 4 – 11 wt.%. The nickel-based alloy composition may further include at least one of: up to 7 wt.% molybdenum; up to 1 wt.% titanium; and up to 3 wt.% niobium.

[0012] In another aspect of the present disclosure, an additive manufacturing component can include the above-identified nickel-based alloy composition. The component can include at least one of: a hot cracking index less than 2.0; a Scheil mushy zone of less than 250K; an equilibrium mushy zone less than 100K; a gamma prime phase fraction at 1200K between 40 and 67 mol%; a gamma prime formation temperature less than 1500K; a topologically close-packed (TCP) formation temperature is between 900K

and 1650K; a crack density of less than 1.50 mm/mm^2; or a hardness between 350 $HV_{0.3}$ and 560 $HV_{0.3}$.

[0013] In accordance with examples, the nickel-based alloy composition can more particularly include: Al: 3.9 – 7.2 wt.%; Co: 6.4 – 12.0 wt.%; Cr: 14.0 – 26.0 wt.%; Mo: 0.4 – 0.7 wt.%; Ta: 2.2 – 4.0 wt.%; Ti: 0.5 – 0.9 wt.%; W: 6.7 – 12.4 wt.%; and Ni: balance. Further, the composition of aluminum may be 4.7 – 6.3 wt.%; the composition of cobalt may be 7.8 – 10.6 wt.%; the composition of chromium may be 17.0 – 23.0 wt.%; the composition of molybdenum may be 0.4 – 0.6 wt.%; the composition of tantalum may be 2.6 – 3.6 wt.%; the composition of titanium may be 0.6 – 0.8 wt.%; and the composition of tungsten may be 8.1 – 10.9 wt.%. An additive manufacturing component can include the above nickel-based alloy composition and have a crack density of 0.09 mm/mm^2. Moreover, the component may exhibit a hot cracking index of 0.58.

[0014] According to other examples, the nickel-based alloy composition can more particularly include: Al: 3.9 – 7.2 wt.%; Co: 6.4 – 12.0 wt.%; Cr: 5.7 – 10.7 wt.%; Mo: 4.2 – 7.8 wt.%; Ta: 2.2 – 4.0 wt.%; Ti: 0.5 – 0.9 wt.%; W: 6.7 – 12.4 wt.%; and Ni: balance. Further, the composition of can be is 4.7 – 6.3 wt.%; the composition of cobalt can be 7.8 – 10.6 wt.%; the composition of chromium can be 7.0 – 9.4 wt.%; the composition of molybdenum can be 5.1 – 6.9 wt.%; the composition of tantalum can be 2.6 – 3.6 wt.%; the composition of titanium can be 0.6 – 0.8 wt.%; and the composition of tungsten can be 8.1 – 10.9 wt.%. An additive manufacturing component can include the above nickel-based alloy composition and have a crack density of 0.12 mm/mm^2. Moreover, the component can exhibit a hot cracking index of 0.50.

[0015] In accordance with other examples, the nickel-based alloy composition may particularly include: Al: 3.9 – 7.2 wt.%; Co: 6.4 – 12.0 wt.%; Cr: 5.7 – 10.7 wt.%; Mo: 0.4 – 0.7 wt.%; Nb: 1.5 – 2.9 wt.%; Ta: 2.2 – 4.0 wt.%; W: 2.8 – 5.2 wt.%; and Ni: balance. Further, the composition of aluminum may be 4.7 – 6.3 wt.%; the composition of cobalt may be 7.8 – 10.6 wt.%; the composition of chromium may be 7.0 – 9.4 wt.%; the composition of molybdenum may be 0.4 – 0.6 wt.%; the composition of niobium may be 1.9 – 2.5 wt.%, the composition of tantalum may be 2.6 – 3.6 wt.%; the composition of tungsten may be 3.4 – 4.6 wt.%. An additive manufacturing component can include the above nickel-based alloy composition and have a crack density of 1.31 mm/mm^2. Moreover, the component may exhibit a hot cracking index of 1.76.

[0016] In still other examples, the nickel-based alloy composition can include: Al: 3.9 – 7.2 wt.%; Co: 6.4 – 12.0 wt.%; Cr: 7.1 – 13.3 wt.%; Mo: 0.4 – 0.7 wt.%; Ta: 2.2 – 4.0 wt.%; Ti: 0.5 – 0.9 wt.%; W: 5.3 – 9.8 wt.%; and Ni: balance. Further, the composition of aluminum can be 4.7 – 6.3 wt.%; the composition of cobalt can be 7.8 – 10.6 wt.%; the composition of chromium can be 8.7 – 11.7 wt.%; the composition of molybdenum can be 0.4 – 0.6 wt.%; the composition of tantalum can be 2.6 – 3.6 wt.%; the composition of titanium can be 0.6 – 0.8 wt.%; and the composition of tungsten can be 6.4 – 8.6 wt.%. An additive manufacturing component can include the above nickel-based alloy composition and have a crack density of 1.37 mm/mm^2. Further, the component can exhibit a hot cracking index of 1.24.

[0017] According to still other examples, the nickel-based alloy composition may include: Al: 4.6 – 8.5 wt.%; Co: 7.7 – 14.3 wt.%; Cr: 4.2 – 7.8 wt.%; Ta: 2.2 – 4.0 wt.%; W:

5.6 – 10.4 wt.%; and Ni: balance. Moreover, the composition of aluminum may be 5.5 – 7.5 wt.%; the composition of cobalt may be 9.4 – 12.7 wt.%; the composition of chromium may be 5.1 – 6.9 wt.%; the composition of tantalum may be 2.6 – 3.6 wt.%; the composition of tungsten may be 6.8 – 9.2 wt.%. An additive manufacturing component may include the above nickel-based alloy composition and have a crack density of 1.44 mm/mm^2. The component may exhibit a hot cracking index of 0.95.

[0018] In accordance with still yet other examples, the nickel-based alloy the composition can include: Al: 4.6 – 8.5 wt.%; Co: 7.0 – 13.0 wt.%; Cr: 5.6 – 10.4 wt.%; Ta: 2.8 – 5.2 wt.%; W: 4.2 – 7.8 wt.%; and Ni: balance. Further, the composition of aluminum can be 5.5 – 7.5 wt.%; the composition of cobalt can be 8.5 – 11.5 wt.%; the composition of chromium can be 6.8 – 9.2 wt.%; the composition of tantalum can be 3.4 – 4.6 wt.%; and the composition of tungsten can be 5.1 – 6.9 wt.%. An additive manufacturing component can include the above nickel-based alloy composition and have a crack density of 1.46 mm/mm^2. Moreover, the component can exhibit a hot cracking index of 0.88.

[0019] Examples are directed to an additive manufacturing component that includes a nickel-based alloy composition; and has a hot cracking index of less than 2.0, a Scheil mushy zone of less than 250K, an Equilibrium mushy zone less than 100K, a gamma prime phase fraction at 1200K between 40 and 65 mol%, a gamma prime formation temperature less than 1500K, and a TCP formation temperature between 900K and 1600K.

[0020] Examples are directed to an additive manufacturing component that includes a nickel-based alloy composition; and has a crack density of less than 1.50 mm/mm^2 and a hardness between 350 $HV_{0.3}$ and 560.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The present invention is further described in the detailed description which follows, in reference to the noted plurality of drawings by way of non-limiting examples of exemplary embodiments of the present invention, in which like reference numerals represent similar parts throughout the several views of the drawings, and wherein:

[0022] Fig. 1 graphically depicts the Scheil-Gulliver model based on the solidification behavior of the alloy for calculating the hot cracking index (HCI) for an embodiment;

CLAIMS

1. A nickel-based alloy composition for additive manufacturing, comprising:

4 – 9 wt.% aluminum;

6 – 15 wt.% cobalt;

4 – 26 wt.% chromium;

2 – 5 wt.% tantalum;

3 – 13 wt.% tungsten; and

balance nickel.

2. The nickel-based alloy composition according to claim 1, further comprising at least one of:

up to 8 wt.% molybdenum;

up to 1 wt.% titanium; and

up to 4 wt.% niobium.

3. The nickel-based alloy composition according to claim 1, wherein the composition of aluminum is 4.5 – 7.7 wt.%, the composition of cobalt is 7.7 – 12.9 wt.%, the composition of chromium is 5 – 23 wt.%, the composition of tantalum is 2.5 – 4.8 wt.%, and the composition of tungsten is 3.3 – 11 wt.%.

4. The nickel-based alloy composition according to claim 3, further comprising at least one of :

up to 7.0 wt.% molybdenum;

up to 0.9 wt.% titanium; and

up to 2.8 wt.% niobium.

5. An additive manufacturing component comprising the nickel-based alloy composition according to claim 1, wherein the component comprises at least one of:

a hot cracking index less than 2.0;

a Scheil mushy zone of less than 250K;

an equilibrium mushy zone less than 100K;

a gamma prime phase fraction at 1200K between 40 and 67 mol%;

a gamma prime formation temperature less than 1500K;

a topologically close-packed (TCP) formation temperature is between 900K and 1650K;

a crack density of less than 1.50 mm/mm^2; or

a hardness between 350 $HV_{0.3}$ and 560 $HV_{0.3}$.

6. The nickel-based alloy composition according to claim 1, wherein the composition comprises:

Al: 3.9 – 7.2 wt.%;

Co: 6.4 – 12.0 wt.%;

Cr: 14.0 – 26.0 wt.%;

Mo: 0.4 – 0.7 wt.%;

Ta: 2.2 – 4.0 wt.%;

Ti: 0.5 – 0.9 wt.%;

W: 6.7 – 12.4 wt.%; and

Ni: balance.

7. The nickel based alloy composition according to claim 5, wherein the composition of aluminum is 4.7 – 6.3 wt.%; the composition of cobalt is 7.8 – 10.6 wt.%; the composition of chromium is 17.0 – 23.0 wt.%; the composition of molybdenum is 0.4 – 0.6 wt.%; the composition of tantalum is 2.6 – 3.6 wt.%; the composition of titanium is 0.6 – 0.8 wt.%; and the composition of tungsten is 8.1 – 10.9 wt.%.

8. The nickel-based alloy composition according to claim 1, wherein the composition comprises:

Al: 3.9 – 7.2 wt.%;

Co: 6.4 – 12.0 wt.%;

Cr: 5.7 – 10.7 wt.%;

Mo: 4.2 – 7.8 wt.%;

Ta: 2.2 – 4.0 wt.%;

Ti: 0.5 – 0.9 wt.%;

W: 6.7 – 12.4 wt.%; and

Ni: balance.

9. The nickel based alloy composition according to claim 9, wherein the composition of aluminum is 4.7 – 6.3 wt.%; the composition of cobalt is 7.8 – 10.6 wt.%; the composition of chromium is 7.0 – 9.4 wt.%; the composition of molybdenum is 5.1 – 6.9 wt.%; the composition of tantalum is 2.6 – 3.6 wt.%; the composition of titanium is 0.6 – 0.8 wt.%; and the composition of tungsten is 8.1 – 10.9 wt.%.

10. The nickel based alloy composition according to claim 9, further comprising at least one of:

up to 0.2 wt% carbon;

up to 0.2 wt% boron; or

up to 3 wt% zirconium.

11. The nickel-based alloy composition according to claim 1, wherein the composition comprises:

Al: 3.9 – 7.2 wt.%;

Co: 6.4 – 12.0 wt.%;

Cr: 5.7 – 10.7 wt.%;

Mo: 0.4 – 0.7 wt.%;

Nb: 1.5 – 2.9 wt.%;

Ta: 2.2 – 4.0 wt.%;

W: 2.8 – 5.2 wt.%; and

Ni: balance.

12. The nickel-based alloy composition according to claim 13, wherein the composition of aluminum is 4.7 – 6.3 wt.%; the composition of cobalt is 7.8 – 10.6 wt.%; the composition of chromium is 7.0 – 9.4 wt.%; the composition of molybdenum is 0.4 – 0.6 wt.%; the composition of niobium is 1.9 – 2.5 wt.%, the composition of tantalum is 2.6 – 3.6 wt.%; the composition of tungsten is 3.4 – 4.6 wt.%.

13. The nickel-based alloy composition according to claim 1, wherein the composition comprises:

Al: 3.9 – 7.2 wt.%;

Co: 6.4 – 12.0 wt.%;

Cr: 7.1 – 13.3 wt.%;

Mo: 0.4 – 0.7 wt.%;

Ta: 2.2 – 4.0 wt.%;

Ti: 0.5 – 0.9 wt.%;

W: 5.3 – 9.8 wt.%; and

Ni: balance.

14. The nickel-based alloy composition according to claim 17, wherein the composition of aluminum is 4.7 – 6.3 wt.%; the composition of cobalt is 7.8 – 10.6 wt.%; the composition of chromium is 8.7 – 11.7 wt.%; the composition of molybdenum is 0.4 – 0.6 wt.%; the composition of tantalum is 2.6 – 3.6 wt.%; the composition of titanium is 0.6 – 0.8 wt.%; and the composition of tungsten is 6.4 – 8.6 wt.%.

15. The nickel-based alloy composition according to claim 1, wherein the composition comprises:

Al: 4.6 – 8.5 wt.%;

Co: 7.7 – 14.3 wt.%;

Cr: 4.2 – 7.8 wt.%;

Ta: 2.2 – 4.0 wt.%;

W: 5.6 – 10.4 wt.%; and

Ni: balance.

16. The nickel-based alloy composition according to claim 15, wherein the composition of aluminum is 5.5 – 7.5 wt.%; the composition of cobalt is 9.4 – 12.7 wt.%; the composition of chromium is 5.1 – 6.9 wt.%; the composition of tantalum is 2.6 – 3.6 wt.%; the composition of tungsten is 6.8 – 9.2 wt.%.

17. The nickel-based alloy composition according to claim 1, wherein the composition comprises:

Al: 4.6 – 8.5 wt.%;

Co: 7.0 – 13.0 wt.%;

Cr: 5.6 – 10.4 wt.%;

Ta: 2.8 – 5.2 wt.%;

W: 4.2 – 7.8 wt.% ; and

Ni: balance.

18. The nickel-based alloy composition according to claim 17, wherein the composition of aluminum is 5.5 – 7.5 wt.%; the composition of cobalt is 8.5 – 11.5 wt.%; the composition of chromium is 6.8 – 9.2 wt.%; the composition of tantalum is 3.4 – 4.6 wt.%; and the composition of tungsten is 5.1 – 6.9 wt.%.