Patented May 20, 1941 2,242,865

UNITED STATES PATENT OFFICE

2,242,865

NICKEL ALLOY

Theodore E. Kihlgren, West New Brighton, Staten Island, N. Y., assignor to The International Nickel Company, Inc., New York, N. Y., a corporation of Delaware

No Drawing. Application June 17, 1940, Serial No. 340,993. In Canada March 16, 1940

5 Claims. (Cl. 75—170)

The present invention relates to nickel casting alloys, and, more particularly, to graphitic nickel alloys having improved castability, mechanical properties and machinability; and articles manufactured therefrom.

It has been known that certain nickel alloys may contain up to about 2% carbon. These alloys, usually referred to as graphitic nickels, carbonized nickel, nickel-carbon alloys, carbon nickels, etc., have been described, for example, in U. S. Patent No. 1,501,906 to Hybinette. The prior nickel-carbon alloys, however, had certain short-comings and disadvantages which greatly restricted their usefulness. Thus, the alloys failed to fill the mold sharply, lacked fluidity and were sluggish. The ability of the alloy to fill the mold sharply and to provide a sound casting is referred to herein as the castability of the alloy. When silicon was present in appreciable amounts the alloys did not possess the desired high mechanical properties. As a result castings of graphitic nickel were unsatisfactory for many commercial applications.

Although attempts have been made to remedy the aforementioned shortcomings, none, as far as is known, has been entirely successful and satisfactory when carried into practice on an industrial scale for the production of commercial products.

I have discovered that the aforesaid problems may be solved in a particularly effective manner and that the art may be provided with articles made of graphitic nickel alloys having an improved combination of properties, as for example, improved castability, machinability, ability to take a ground surface, corrosion resistance, surface structure, moderate resistance to galling, etc.

It is an object of the present invention to provide nickel-carbon alloys containing regulated amounts of co-present silicon and manganese in balanced proportions and characterized by an improved combination of castability, machinability, and mechanical properties over a similar nickel-carbon alloy not containing the regulated amounts of co-present silicon and manganese.

It is another object of the present invention to provide graphitic nickel alloys having exceptionally fine surface characteristics which permit the alloys to take a ground surface and to take perfect polishes.

It is a further object of the present invention to provide improved articles manufactured from graphitic nickel alloys, as for example, improved pressure castings which are machined or polished to a very high degree of perfection, improved members for pumps, valves and the like having a useful degree of resistance to "scuffing," and the like.

Other objects and advantages will become apparent to those skilled in the art from the following description.

I have found that nickel alloys containing controlled and balanced proportions of carbon, manganese and silicon possess properties which make them especially useful for certain purposes where ability to fill the mold sharply, soundness of casting, good mechanical properties and machinability are required. Broadly stated, these properties can be obtained in graphitic nickel alloys by maintaining the composition within the approximate ranges given in Table I.

Table I

Element	Percentage
Carbon	0.65 to 2
Silicon	1 to 4
Manganese	0.5 to 4
Nickel	Balance

It will be seen that the nickel will be at least about 90% of the alloy. Preferably, the total silicon plus carbon content is more than about 2%. If silicon and/or manganese falls below the approximate minimum values set forth, the improved combination of good castability, good mechanical properties and good machinability is endangered. Certain deviations from the composition set forth, particularly when silicon is too low, will result in loss of the desired castability, i. e., decreased casting properties such as fluidity and ability to fill the mold sharply, and will result in a very poor surface quality due to "cold shuts", "folds", "laps", and the like. Particularly when manganese is below the minimum set forth, the mechanical properties are adversely affected. The co-presence of silicon and manganese is necessary to obtain the combination of desirable strength properties; improved distribution of graphite, particularly at the lower carbon levels, say about 0.65% to about 1.1%; and good castability, and good fluidity. Carbon must be present in excess of about 0.5%, in conjunction with proper silicon and manganese, to secure marked improvement in machinability, and a minimum of about 0.65% carbon appears desirable for best results. As will be apparent to those skilled in the art, other minor constituents and impurities such as cobalt, copper, iron, magnesium, aluminum, titanium, phosphorus, sulfur, etc., may be

present in the alloys. Cobalt and copper may be present as elements usually associated with nickel and its alloys. Small amounts of magnesium, for example about 0.05 to 0.1%, appear to increase the ductility of the alloys particularly when sulfur is present. Strengthening elements such as aluminum, titanium, and the like, which in many instances are objectionable at low carbon levels due to film forming tendencies, may be quite tolerable in appreciable amounts in carbon nickels, from a castability angle, and develop fairly high properties along with good machinability. It is to be understood that when nickel is said to constitute the "balance" or when I say that the balance is "substantially all nickel", I include within the scope of the expressions nickel and also minor constituents and impurities which may be present in such amounts as occur in commercial nickel products, or in amounts not adversely affecting the desired properties of the nickel alloy.

In carrying the present invention into practice, it is preferred to incorporate in nickel the essential elements, carbon, silicon and manganese, within the approximate ranges given in Table II.

Table II

Element	Percentage
Carbon	0.8 to 1.3
Silicon	1.0 to 2.25
Manganese	0.5 to 2
Nickel	Balance

Alloys made in accordance with the present invention possess adequate toughness, strength and ductility and exhibit mechanical properties within the approximate ranges given in Table III, the particular properties obtained being determined by the proportions of carbon, silicon and manganese.

Table III

Tensile strength	p. s. i.	20,000 to 45,000
Yield point	p. s. i.	12,000 to 25,000
Elongation	percent	5 to 13

P. s. i.=pounds per square inch.

Increasing carbon contents above about 1% tends to lower the strength properties and the ductility toward the minimum values. A satisfactory balance of castability, mechanical properties and machinability is obtained when the composition falls with the approximate ranges given in Table II. Carbon and manganese have a marked effect on the tensile properties while silicon has a mild hardening effect on the matrix but a marked effect upon the amount and distribution of graphite for a given total carbon content. An alloy containing about 1% carbon and substantially free from manganese and silicon has a tensile strength of about 20,000 to 25,000 pounds per square inch. Another alloy also containing about 1% carbon and, in accordance with the present invention, containing 1% manganese and about 2% silicon has excellent castability and a tensile strength of about 35,000 pounds per square inch. Another alloy containing similar amounts of carbon and silicon and about 4% manganese possesses fairly satisfactory casting properties combined with a tensile strength of about 45,000 pounds per square inch and an elongation of about 13% instead of an elongation of 7.5% as exhibited by the alloy substantially free from manganese and silicon and the alloy containing 1% manganese and 2% silicon. A similar effect is noted at the 1.5% carbon level although the mechanical properties in general are somewhat lower. An alloy containing 1.5% carbon and substantially free from manganese and silicon had a tensile strength of only 16,000 pounds per square inch with an elongation of about 5%. The presence of about 2% silicon and about 3.5 to 4% manganese in the 1.5% carbon alloy raises the tensile strength to about 26,000 pounds per square inch with an elongation of about 8%.

The alloys of the present invention possess far superior castability to that of ordinary nickel with 0.1 to 0.25% carbon. They can be cast with very little difficulty, in comparison to ordinary cast nickel, into complicated shapes which are pressure tight, for example, pump bodies and other pressure castings. The ease of machining exhibited by the alloys of the present invention increases with the carbon content, and a carbon nickel with about 1% carbon, 2% silicon and 1.5% manganese which would have a tensile strength of about 35,000 to 40,000 pounds per square inch is machined with about the same facility as a pearlitic grey iron of comparable tensile strength. The effect of carbon content on the machinability of the graphitic nickel alloys is demonstrated by simple sawing tests which comprise measuring the time required to make a cut through a fixed cross section under constant load and speed. Machined cylinders, one and three-quarters inches in diameter, were subjected to sawing tests carried out on a gravity feed power saw, using a new blade for each casting, and the average cutting time noted. The effect of carbon content on the cutting time (average for two cuts in minutes) is illustrated in Table IV.

Table IV

Alloy No.	Carbon	Cutting time
	Percent	*Minutes*
1	0.04	10.1
2	0.52	9.2
3	0.76	5.9
4	0.98	4.4
5	1.28	2.6

Alloy No. 1 was a low manganese, low silicon nickel while alloys Nos. 2 to 5 contained 1.2 to 1.45% manganese and 2.06 to 2.2% silicon. It will be apparent that carbon must be present in excess of 0.5%, e. g., about 0.65%, to secure marked improvement in machinability. A grey cast iron of about 40,000 pounds per square inch tensile strength gave about the same order of machinability as a 1% carbon nickel containing manganese and silicon, an average time of 4.25 minutes being required for two cuts. In actual machining operations, the machinability of the present alloys is much superior to that of ordinary nickels under similar machining conditions of cut, feed and revolutions per minute. No chattering occurs and the chips are short in contrast to the long continuous chips obtained in machining ordinary nickel.

The improved alloys also possess improved surface characteristics. The alloys possess the ability to take a high finish and even large castings can be made which show no pits after machining, a characteristic which has proved of great value in chemical process equipment, in filter heads, pumps, of both vane and gear types, sleeves, and the like. They also possess advantage for glass molds and the like because of the excellent surface attainable and other desirable characteristics.

The carbon nickels provided by the present invention possess a useful degree of "scuffing" resistance and are particularly suitable in applications such as pumps for handling various liquids, e. g., cellulose acetate, where the impeller may rub against the pump casting. In such applications galling occurred with the previously used materials.

The microstructure of the carbon nickels provided by the present invention is primarily dependent upon the proper adjustment of the silicon content for a given carbon content. For example, a 1% carbon nickel without silicon has its carbon distributed in the form of rosette-like or globular shapes very similar to "temper" carbon in malleable cast iron. By adding silicon within the ranges contemplated by the present invention, for example, in amounts of about 1.5 to 2%, the graphite distribution of the alloy is markedly altered, particularly at the lower carbon levels, say about 0.65% to about 1.1%, and the graphite in carbon nickels containing more than about 0.65% carbon appears as flakes and generally is more uniformly distributed through the matrix than in the silicon-free alloys. Such a structure is accompanied by improved machinability. Below about 0.65% carbon, carbon nickels containing silicon over 1% still retain the graphite as globular or rounded patches. Thus, alloy No. 2 of Table IV is characterized by a small amount of graphite occurring principally in rounded patches quite widely separated while alloy No. 3 has a considerable amount of graphite occurring in long flakes distributed more or less at random.

Carbon nickel castings having the compositions contemplated by the present invention can be readily produced directly from arc furnace or oil-fired crucible furnace melts or from melts produced in any other convenient furnace, including the ordinary cupola normally used for cast iron. Graphite, electrode butts, charcoal, coke, and the like form readily available sources for carbon while electrolytic nickel, nickel shot, nickel alloy shot, powdered nickel and the like may be used for the base charge. In crucible melts, for example, of about 100 to 150 pounds, it is probably preferable to use high carbon nickel pig for the charge, diluting with electrolytic nickel to obtain the desired carbon level and then adding the desired amounts of silicon and manganese. This method permits closer control of composition. In preparing the high carbon nickel pig, an arc furnace works very well and no difficulty is encountered in obtaining a high carbon nickel pig for melting stock. It would appear that by means of spoon tests, fracture tests and quick carbon determinations while the melt is being held in the furnace, rather good control can be secured in large arc furnace heats, and adjustments made, if they be required. The use of the cupola for the production of carbon nickel affords a cheap method which also permits the reclamation of low grade nickel scrap. A low sulfur coke should be used and a suitable slag may also be found helpful to reduce the sulfur "pick-up."

A very satisfactory alloy which possesses an excellent combination of castability, physical properties and machinability is secured in an alloy having the composition set forth in Table V. Such an alloy will possess tensile strengths of about 35,000 to 40,000 pounds per square inch and a minimum elongation of about 7 to 10%.

Table V

Element	Percentage
Carbon	0.9 to 1.0
Silicon	1.5 to 2
Manganese	1 to 1.5
Nickel	Balance

In order that those skilled in the art may have a better understanding of the present invention, illustrative examples of some alloy compositions and resulting physical properties are given in Table VI and Table VII.

Table VI

Alloy No.	Percent C	Percent Si	Percent Mn	Percent Ni
3	0.76	2.20	1.45	Balance.
4	0.98	2.18	1.20	Do.
5	1.28	2.16	1.40	Do.
6	0.98	2.17	3.91	Do.
7	1.0	2.0	1.5	Do.
8	0.88	2.21	0.99	Do.
9	1.35	2.11	3.60	Do.
10	1.66	3.95	1.5	Do.
11	1.27	4.10	0.94	Do.

Table VII

Alloy No.	Y. P.	T. S.	Percent El.	B. H. N.
6	25.9	45.7	13.0	104
7	20.0	35.0	*7-10	----------
8	19.8	37.8	12.0	96
9	17.6	26.2	9	88
10	18.3	24.9	5	99
11	14.3	21.0	5	77

Y. P.=yield point in thousand pounds per square inch (0.5% Extension under load).
T. S.=tensile strength in thousand pounds per square inch.
Percent el.=per cent elongation in 2 inches.
B. H. N.=Brinell hardness number (1000 kg. load).
*Minimum values.

The present invention contemplates, as improved articles of manufacture, castings made of the improved carbon nickel alloys described hereinbefore. Such articles include pumps and pump members or elements with a useful degree of resistance to scuffing such as pump bodies, cylinders, casings and housings; rotors including impellers, vanes, gears, cams and buckets; heads or closing plates; etc. Other castings include improved pressure castings free from leakers, shrinkage cavities and other unsoundness; valves, such as gate valves, and valve members, such as seats and discs; chemical process equipment, including hoppers, bowls, containers and the like for handling emulsions, etc., especially where freedom from metal contamination or a fine, smooth finish is desirable; and improved castings capable of being machined and/or polished to a very high degree of perfection such as glass and plastic molds, filter liners, and the like.

The present alloys do not undergo any allotropic transformation on heating and cooling in contrast to cast iron and steel. In consequence of this and other factors the alloys of the present invention are particularly suitable for articles, subject to repeated heating and cooling, particularly local heating and cooling as in brake drums for aircraft and parts of internal combustion engines. Tests involving rapid heating followed by quenching show that the alloys remain smoother and are less subject to cracking than the usual cast irons. The thermal conductivities of the new alloys are higher than that of gray cast iron, an advantageous property not only

in brake drums and internal combustion engine parts but also for molds of various types.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such variations and modifications are considered to be within the purview and scope of the appended claims.

I claim:

1. A casting comprising as essential ingredients 0.65% to 2% carbon, 1% to 4% silicon, the silicon and carbon together exceeding about 2% of the alloy, 0.5% to 4% manganese, and the balance substantially all nickel, said casting being characterized by sharp detail and pressure tightness, and by a combination of machinability, adequate mechanical properties and a useful degree of resistance to "scuffing."

2. An alloy comprising as essential ingredients approximately 0.9% to 1% carbon, 1.5% to 2% silicon, 1% to 1.5% manganese, and the balance substantially all nickel, said alloy having a tensile strength of about 35,000 lbs. per square inch, an elongation of about 7% combined with good castability and machinability.

3. An alloy comprising as essential ingredients approximately 0.8% to 1.3% carbon, 1.0% to 2.25% silicon, 0.5% to 2% manganese and the balance substantially all nickel, said alloy being characterized by adequate toughness and ductility combined with improved castability, machinability and good mechanical properties.

4. An alloy comprising as essential ingredients 0.65% to 2% carbon, 1% to 4% silicon, 0.5% to 4% manganese, and the balance substantially all nickel.

5. A nickel-carbon alloy containing about 0.65% to about 1.1% carbon, about 1% to about 4% silicon, the total silicon and carbon exceeding about 2%, about 0.5% to about 4% manganese, and the balance substantially all nickel, said alloy being characterized by a microstructure comprising carbon occurring largely in the form of flake graphite distributed through the matrix.

THEODORE E. KIHLGREN.