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ARMOR PLATE

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This invention relates to armor plate and the like bullet-resistant articles.

The so-called bullet-proof steels are used on tanks, armored cars, battleships, for gun shields, and for other military uses where resistance to bullets is needed. Speaking generally two types of armor plate have been used heretofore, viz., homogeneous and face-hardened. The modern trend has been to the use of homogeneous armor plate, which comprises a high-grade alloy steel heat treated to give great strength and ductility. The composition and mechanical characteristics of such plates are uniform throughout. Their bullet resistance depends upon the development of sufficient strength to resist bullet penetration, together with sufficient ductility to prevent destruction of the plate under ballistic impact. In the production of face-hardened material the plates are carburized to enrich the exposed face in carbon, and the carburized plate is then heat treated to harden the surface.

To combat the efficacy of such armor plate there have been developed small-arms bullets capable of penetrating the thicknesses of such plates which can be used practically. For instance, the United States Army at present uses for this purpose .30 and .50 caliber bullets consisting of a hardened tungsten steel core covered with a jacket of cupro-nickel alloy. The penetrating power of such bullets depends upon the hardness of the core, and the jackets function merely to protect the rifling of the firearm against rapid depreciation which would occur if the extremely hard cores moved in direct contact therewith.

Both of these types of armor plate are subject to serious disadvantages, both economic and physical. Neither type is hard enough to shatter the cores of modern armor-piercing bullets, so that their bullet resistance depends upon suitable combinations of strength and ductility in plates of suitable thickness. The homogeneous type of plate behaves characteristically under bullet impact, showing a petal-like structure in the back at the point of impact, which opens out as the plate gives way under the force of the projectile. This indicates a general break-down of the metal in the vicinity of the point of impact, so that the utility of the plate may be seriously affected by repeated hits, especially in a given area.

Theoretically the face-hardened plates should be superior to the homogeneous type, because of the great hardness of the surface, and actually they do show somewhat superior ballistic qualities. Despite that superiority however, the trend has

been away from surface hardened plates because of their fabricating properties and behavior in use. For example, the face-hardened plates available heretofore are characterized by the fact that buttons are thrown from the rear of the plates when a bullet strikes, so that these plates are inherently a source of danger. They also have a pronounced tendency to spall, and to crack and shatter generally. As to their fabrication, all such operations must be completed prior to heat treatment, as the hardness of the hardened plate precludes forming, cutting, drilling, etc. This entails the further disadvantage that costly jigs are needed for heat treatment, to minimize warpage, for the plates can not be satisfactorily straightened after hardening. For these reasons the trend has been away from face-hardened plate, despite the superiority which should theoretically attend the use of highly hardened surfaces for the behavior of prior face-hardened plate has led to the belief that spalling, throwing buttons, and fabricating difficulties inhere in surface hardened material.

In consequence of these and other factors the art has heretofore lacked a satisfactory armor plate.

It is among the objects of this invention to provide bullet-proof armor plate whose ballistic limit, at least in thicknesses upwards of about one-fourth inch, is superior to that of the plates heretofore available, in which a hard coherent surface integral with a high quality alloy steel backing cooperates to resist penetration without spalling, fingering and similar disadvantageous results, which can be formed and fabricated readily after heat treatment, which overcomes many of the disadvantages of and is generally superior to the materials hitherto available for this purpose, and which in a special embodiment is adapted to cause fragmenting of the cores of armor-piercing bullets.

It has been known for some time that steels of suitable composition may be rendered exceptionally hard in their marginal layers by nitrogenation, for instance, by the familiar ammonia gas process. These nitrided surfaces are admirably adapted to resist wear, being substantially harder than carburized surfaces, but experience has shown that, as a general rule, they tend to spall and crack under severe impact. Accordingly, it has been thought that nitriding is not applicable where the nitrided surface is exposed to heavy impact shocks, owing to inherent deficiencies in toughness of the nitride layer and in its adherence to the core.

I have discovered, and it is on this that the invention is predicated in part, that, contrary to what would be expected, nitrided armor plate is superior to the armor plates heretofore available, is free from the disadvantages which attend both homogeneous and carburized plates, and affords superior resistance to armor-piercing projectiles. I have found further that particularly desirable results flow from the use of plates nitrided to render the exposed surface harder than the cores of the armor-piercing projectiles to which they are exposed.

Stated in other words, I have discovered that armor plate embodying ballistic properties surpassing those known heretofore may be obtained by nitriding the surface of a plate of steel possessing suitable mechanical properties and capable of forming a nitride surface of appropriate hardness and depth. Not only do the plates provided by the invention excel ballistically both the homogeneous and the face-hardened plates used hitherto, but also they are superior from procedural and behavior standpoints. For instance, they show the best behavior insofar as concerns spalling and throwing buttons. In addition, the plates provided by the invention can be bent, straightened and subjected to comparatively difficult and accurate fabricating and shaping operations, in contrast to plates face-hardened by carburizing. Accordingly, the nitrided armor plate described and claimed herein fully meets the three requirements of armor, and is superior in all three regards to those previously known and used.

The plates provided by the invention possess substantially no tendency to crack, spall, form petals or fingers, or to throw buttons, so that they are superior to the plates used heretofore. This avoidance of these physical defects of the prior plates constitutes an important feature of the invention and is entirely contrary to normal expectancy. Thus the behavior of carburized plates under projectile impact would lead those skilled in the art to anticipate that nitrided plates would show the same disadvantageous phenomena to a greater degree, because of the greater hardness of nitrided surfaces and their known spalling and cracking proclivities. Actually, however, my tests have shown that nitrided plates in accordance with the invention are free from the tendencies which have militated against carburized plates, and that their action differs in kind from that of carburized plates instead of in the normally expected degree. In other words nitrided steels possess the hitherto unknown property of being adapted to enhance the ballistic properties of steel, and to shatter the bullet cores upon impact, thereby changing the characteristic behavior of the steel when used for armor plate.

In the practice of the invention the plates are formed from a steel capable of forming a suitable nitride surface and of providing sufficient strength and ductility to back up the nitrided surface, i. e. to absorb and withstand the impact force of the bullet and thus to reinforce the harder nitrided surface and keep it from breaking. The most satisfactory results are had with nitrided surfaces harder than the bullet cores, so that upon impact with the plate the bullets are fragmented. As just indicated, the steel also must be capable of developing suitable strength and ductility in order to reinforce the nitrided surface properly. If the plate is too hard the backing will not possess sufficient ductility to maintain the hardened surface, while if it is too

soft it will not be strong enough to properly reinforce the nitrided surface. The importance of these factors and their correlation will be understood by those skilled in the art.

The alloys used in the practice of the invention should contain an element, such as aluminum or vanadium, which adapts it to satisfactory nitride hardening, and the nitriding element, or elements, most suitably is such as to cause the hardening to take place to as great depth as possible. The alloy also must contain other elements in sufficient quantities to provide the aforementioned mechanical properties in the backing. The common nitriding elements, e. g., vanadium, chromium or molybdenum may also contribute to the attainment of suitable mechanical qualities. Various alloys adapted to the ends of the invention are known in the art.

The alloys are processed, as by rolling, to provide plates of the desired thickness, and the plates are then nitrided by any appropriate process, as by the well known ammonia gas treatment at elevated temperature. For the purposes of the invention it is necessary to harden only the exposed surfaces of the plate, although for simplicity both surfaces may be hardened. The plates may be heat treated to develop the mechanical properties of the body of the plate before nitriding, such a heat treatment being dependent, of course, on the particular steel involved. After this it can be shaped, straightened cut, drilled, etc., and no further warpage occurs at the relatively low temperatures used in nitriding.

Steels containing aluminum have a marked tendency to decarburize at the surface during prolonged heating. Decarburization is known to be deleterious for good nitriding, and accordingly care should be taken to produce plates free from scale and free, or comparatively free, from decarburized surfaces prior to the nitriding operation.

As a non-restrictive example of an alloy suitable for use in the practice of this invention reference may be had to the following steel, which has demonstrated itself to be especially adapted for use in making the new armor plate:

	Per cent
Aluminum.....	0.8 to 1.1
Carbon.....	0.4 to 0.5
Chromium.....	1.0 to 1.25
Manganese.....	0.6 to 0.8
Molybdenum.....	0.6 to 0.8
Vanadium.....	0.2 to 0.3

This is essentially a chrome-molybdenum-vanadium steel capable of giving the necessary mechanical properties upon suitable treatment. Its aluminum content functions primarily to confer substantially nitriding properties. Plates of this steel may be heat treated to develop their mechanical properties by soaking them at 1700° F., and then quenching in oil. Thereafter the plates are tempered by heating to approximately 1200° F., and after being soaked through at this temperature they are cooled in air or oil to secure a hardness of approximately 390 Brinell.

This alloy is capable of developing a nitrided case whose hardness is approximately 1000 Vickers Brinell, and approximately 0.03 inch in thickness. The hardness thus developed is substantially above that possessed by the cores of present day armor-piercing bullets, and the plates are capable of causing shattering of the cores when the bullet strikes the plate. My tests have indicated that where penetration occurs it was

not because the core has not been broken up, but because the plate itself, due to its thickness, does not possess sufficient mechanical strength to withstand the impact force of the high velocity. But even in such cases the bullets are generally broken up, as shown by the fact that the fragments are found behind the plate.

The resistance of the armor plate provided by this invention to penetration is generally, and substantially superior, for any given thickness, compared with the plates used prior to this invention. As indicative of this reference is made to tests of armor plate made from steel of the foregoing composition. In one series of tests nitrided and heat treated plates of the steel 0.252 inch thick were shot at with .30 caliber-167 grain armor-piercing ammunition, the velocity of the bullets at impact being recorded by a chronograph. The results were as follows:

Velocity	Result
1886 f. s.	Bullet broken up. Small dent on front of plate, small bulge on back.
1962 f. s.	Same result.
2006 f. s.	Same result.

Penetration of these plates did not occur until the velocity of the bullet reached or exceeded 2022 foot-seconds, and in penetrating the plate the bullet formed a small hole corresponding to the size of the bullet, but there was no fingering, spalling or cracking. These tests show the superiority of the armor plate provided by this invention as compared with others, inasmuch as the ballistic limit of the best prior homogeneous plate of the same thickness is about 1750 foot-seconds, while that of a corresponding carburized plate is about 1900 foot-seconds. Accordingly, for a given thickness, the ballistic limit of these plates is the maximum yet available. This series of tests also showed that the nitrided steels behave differently from other bullet-proof armor, because up to penetration the effect of increasing velocities has no increased impact effect. On the other hand, homogeneous plate, for example, always shows an increasingly large bulge, with an increasingly large opening at its center in the back of the plate, and with the petals, or fingers opening up progressively, as the velocity increases.

With a given nitrided face the ballistic limit of the plate increases according to its total thickness. This result, and further evidence of the superiority of the nitrided armor plate, is shown by the following tabulation, which gives the results of actual tests to determine the ballistic limits of the plates provided by this invention as compared with those of the previously available plates:

Approximate ballastic limits

Thickness of plate	Best homogeneous plate	Best carburized plate	Nitrided plate
3/16"	1550 f. s.	1750 f. s.	1750 f. s.
1/4"	1750 f. s.	1900 f. s.	1950 f. s.
3/8"	2150 f. s.	2200 f. s.	2450 f. s.
1/2"	1650 f. s.	1950 f. s.	2250 f. s.

In making the foregoing tests the plates up to and including 3/8 inch were tested with .30 caliber-165 grain armor-piercing ammunition, and

the 1/2 inch plate was tested with .50 caliber-750 grain bullets of the same type.

It will be observed from the foregoing tabulation that in every instance the nitrided plates were substantially superior to the best homogeneous plates in resistance to penetration, and that the superiority increases with the thickness of the plate. Also, the nitrided plates are appreciably superior to the carburized plates, except at a thickness of 1/8 inch. But even with thin plates the nitrided armor of this invention possesses greater utility than the carburized plates, this being manifested by the fact that they do not spall and throw "buttons," and also because they can be formed and straightened and otherwise subjected to fabricating operations after being heat treated. Thus they avoid the disadvantages which have brought carburized plates into disrepute in ordnance circles despite the fact its ballistic qualities exceed those of homogeneous plate.

As further showing the benefits to be derived from the invention, reference is made to other tests of 1/2 inch plates like those shown in the foregoing tabulation. Before being nitrided these represent high quality homogeneous armor plate. When shot at with .50 caliber-750 grain bullets they exhibited the properties characteristic of homogeneous materials, viz., formation of petals at the back. After being nitrided, however, the plates showed no petals or fingering, and the result of increasing the impact velocity up to the ballistic limit was merely to batter up the front of the plate a little more. And even at penetration there was no spalling, the only result being the production of a hole approximately the size of the bullet. In addition, the ballistic limits of the plates were improved as a result of the application of nitriding in accordance with the invention, the increase being from about 1650 foot-seconds to about 2250 foot-seconds.

The invention is not restricted to practice with the steel alloy just described, but is applicable to other alloys capable of producing the necessary surface hardness and mechanical properties to back up the surface, as referred to previously. For instance, nitrided armor plates embodying the advantages of the invention have been made from an alloy containing about 0.35 per cent of carbon, about 0.5 per cent of manganese, about 1.4 per cent of chromium, about 1.2 per cent of aluminum, and about 0.18 per cent of molybdenum. When nitrided and heat treated these plates showed ballistic results substantially better than those of the previously available homogeneous armor plate. Other alloys than these may be used also, such as Cr-Mo-V steels free from aluminum.

According to the provisions of the patent statutes, I have explained the principle of my invention and have described what I now consider to represent its best embodiment. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

I claim:

1. As a new article of manufacture, armor plate formed from a plate of alloy steel containing about 0.8 to 1.1 per cent of aluminum, about 0.4 to 0.5 per cent of carbon, about 1 to 1.25 per cent of chromium, about 0.6 to 0.8 per cent of manganese, about 0.6 to 0.8 per cent of molybdenum, and about 0.2 to 0.3 per cent of vanadium, said plate having its exposed surface provided

with a hard bullet-shattering nitrated layer integral with and adherent to the body of the plate, and said layer and body portion cooperating to resist penetration of the plate under ballistic impact.

2. As a new article of manufacture, armor plate formed from a plate of alloy steel containing about 0.8 to 1.1 per cent of aluminum, about 0.4 to 0.5 per cent of carbon, about 1 to 1.25 per cent of chromium, about 0.6 to 0.8 per cent of

manganese, about 0.6 to 0.8 per cent of molybdenum, and about 0.2 to 0.3 per cent of vanadium, said plate having its exposed surface provided with a hard bullet-shattering nitrated layer integral with and adherent to the body portions of the plate, and the plate being heat treated to render the body portion strong and ductile and thereby to reinforce said layer and resist penetration under ballistic impact.

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