

TITLE OF THE INVENTION

STEEL SHEET HAVING EXCELLENT PROCESSING CHARACTERISTICS,
MANUFACTURING METHOD THEREFOR, AND GALVANIZED STEEL SHEET
AND A RESIN COATING STEEL SHEET

BACKGROUND OF THE INVENTION

Field of the Invention

Hot rolled steel sheets and cold rolled steel sheets are used in a wide variety of applications as outer panels for automobiles and household electrical appliances with various characteristics required for each different application. For example the metal sheet used in computers and household appliances such as VTR (video tape recorders) and tape recorder chassis often require punching processing of movable chassis parts. The edges of these parts ideally should not have any burrs projecting out any more than a specified height from the part surface. For example many times a hole is punched out, for the pin forming the shaft of the VTR head, however when burrs are present this pin cannot be inserted during the assembly process. Also, troubles may occur such when a sliding part binds or does not function well when positioned at the punched surface, or when the "burr" collapses and causes an electrical short.

Description of the Related Art

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Conventionally, low-carbon Al killed steel is usually employed in these kind of material applications such as punch processability. In this low-carbon Al killed steel, the carbon precipitates into a rough crystal particle layer of brittle cementite (iron carbide) effective in the generation of cracks during the punch process so that few burrs occur, and friction wear and shearing load can be kept small. MnS precipitates has the same effect on generation of cracks and the same results as with cementite have been confirmed.

However precipitates like cementite and MnS are dominant elements in controlling critical metal deformation ability, their secondary phase which is an origin of crack generation, causes problems during extrusion flange and stretch-flangeability processes. Therefore, even though the low-carbon Al killed steel is fine for punch processability, it is poorly suited for applications in which the edge of the punched surface must undergo secondary processing such as flange forming or stretch-flangeability.

Recently on the other hand, in order to produce ever more complicated shapes for the latest machined products and also meet user demands for more simplified press forming, the flange characteristics and stretch-flangeability processing for products must attain a yet superior level. Currently, in order to meet these demands, much use is made of IF-based steel which is super-low

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carbon steel added with carbon - nitrogen compound elements such as tin or niobium in prescribed amounts.

This IF-based steel having low yield stress, high elongation and superior press-formability has come to be widely used as a part material in processes accompanying a high degree of material deformation such as automobile body material. However conventional IF-based has drawbacks such as poor punch processability compared with low-carbon A1 killed steel and large burrs on the edges after punching. The finish surface roughness and cutting chip disposal during machining are also unsatisfactory, making the IF-based steel impractical for use according to the particular application.

In other words for press forming of household appliances and automobile parts which are mainly made by being punched out from metal blanks, the above mentioned IF-based steel is unsuitable in spite of superior general forming because of poor punch processability compared to low-carbon A1 killed steel and large burrs on the edges of the steel after punch processability. For instance when used in automobile parts sections of the steel with these burrs have poor adhesion after electro-precipitation processing causing bad effects like corrosion. Another problem is that when stacking boards of punched metal sheet for shipping, a metal powder is generated due to friction wear from the burrs during transport which in turn scratches the product surface. Many applications require drilling or thread cutting, however the inferior finish



surface roughness and cutting chip disposal of the IF-based steel from machining are pointed out as drawbacks.

In order to improve the punch processability (and machinability during machining), method related later are feasible. However, in spite of the fact that only a mere portion of the metal is actually being punched, the mechanical properties of the other portions of the metal must be sacrificed, causing insufficient strength to become a serious problem.

Various technical methods have been tried to improve the quality of the punched portions of the steel sheets such as correct clearances and utilizing various punch and die shapes. Methods have been proposed for the workpiece material such as hardening of the steel sheet or hardening the surface layer of the steel sheet. One specific example of a steel sheet hardening method is addition of reinforcing solid solution elements such as phosphorus. Another specific examples of hardening the surface of the steel is a method for applying plastic strain to the surface layers by rolling the steel sheet after annealing or a method for nitriding or carburizing the surface (Japanese Patent Laid-open Nos. Hei 1-255626, 2-133561, 3-199343 and 3-202442) etc. However in the former method, though the punch processability is improved, the essential mechanical properties of steel such as elongation and the r value deteriorate greatly. In the latter method of nitriding or carburizing, special equipment is required. Methods for generating large amounts of MnS precipitates

material by adding manganese and sulfur has also been proposed (see Japanese Patent Laid-open Nos. Hei 1-230748 and 6-73457). However, these methods greatly increase the amount of sulfur in the steel, not only making the steel prone to cracks during processing under heat but also creating a new problem of frequent occurrence of point defects referred to as blow holes and blisters and surface defects referred to as slivers.

In view of the above, rather than just meeting demands for overall satisfactory forming, the steel also has to meet needs for superior cutting and punch processability demanded for steel in household appliance and automotive products. What is urgently needed is not a huge increase in additives such as sulfur but development of an improved steel with constituent elements near those of super-low carbon IF-based steel while also possessing superior forming and punch processability characteristics.

Galvanizing the steel and then applying a plastic layer on the galvanized surface is known as a basic process for preventing corrosion and improving the outer appearance or for inhibiting fingerprints during handling (improving fingerprint resistance). However steel sheet used in electrical panels or electrical equipment boxes normally must have the box electrically grounded, making electrical conductivity of the box an essential characteristic. However in order to assure this electrical conductivity the plastic layer cannot be made sufficiently thick enough to guarantee resistance to corrosion or fingerprints. To



solve this problem, method was proposed for galvanizing the steel and then using an extremely thin organic plastic layer to improve fingerprint resistance while still being thin enough to provide adequate surface conductivity for grounding of the steel. The extremely thin organic plastic layer however proved insufficient to simultaneously meet demands for both electrical grounding and fingerprint resistance. Therefore development of a surface-treated steel providing satisfactory electrical grounding and fingerprint resistance was still needed.

SUMMARY OF THE INVENTION

In consideration of the foregoing situation, it is an object of this invention to provide a steel sheet by means of good adjustment of chemical constituents, which maintains the superior forming and mechanical properties of conventional IF-based steel sheet, with no problems such as internal defects or surface defects occurring, and also offers good punch processability with no burrs occurring.

Another objective is to provide superior forming, which in this invention, are properties demonstrating superior processing not only for deep draw and protrusion forming but also for flange processing and stretch-flangeability after punching the steel.

A still further objective of the invention is to provide a galvanized steel sheet having good machinability or processing by using the steel sheet mentioned above as a base material and galvanizing the surface.

A yet further objective of the invention is to provide the steel sheet with a plastic layer having good resistance to corrosion and fingerprints and no loss of grounding ability, by means of applying a plastic layer over the galvanized surface.

An additional object of the invention is to provide a reliable method for manufacture of a steel having the above characteristics, that is both stable and suitable for production on an industrial scale.

In order to obtain the above objects, the steel of this invention must satisfy conditions for:

Carbon of 0.0010 to 0.010% by weight and more preferably 0.0010 to 0.008% by weight;

Silicon of 1% or less by weight and more preferably 0.25% or less by weight;

Manganese of less than .1 to 1% by weight and more preferably 0.2 to 1% by weight;

Phosphorus of less than 0.1% by weight and more preferably less than 0.05%;

Sulfur of 0.01 to 0.025% by weight;

Nitrogen of less than 0.01% by weight;

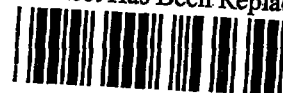
Tin of less than 0.2% by weight and more preferably less than 0.15% and further satisfying:

$$(Ti^*/48)/(C/12 + S/32) = 0.8 \text{ to } 4.0$$

However,

$$Ti^* = Ti - (48/14)N$$

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with further conditions of internally including mainly $\text{Ti}_4\text{C}_2\text{S}_2$ and the remainder comprising iron and unavoidable impurities.

The precipitates composed mainly of $\text{Ti}_4\text{C}_2\text{S}_2$ preferably has a size of 1,000 to 10,000Å and a precipitation count of 5×10^3 pcs/mm² (preferably less than 5×10^5).

The steel of this invention is cold rolled or hot rolled and when hot rolled, the value calculated from said $(\text{Ti}^*/48)/(\text{C}/12 + \text{S}/32)$ is in the range of 1.0 to 3.0 and the size of the precipitates mainly of $\text{Ti}_4\text{C}_2\text{S}_2$ is 1,000 to 10,000Å and preferably said precipitates have a count of 5×10^3 pcs/mm².

When cold rolled, the value calculated from said $(\text{Ti}^*/48)/(\text{C}/12 + \text{S}/32)$ is in the range of 0.8 to 4.0 and more preferably in the range 1.0 to 2.5. The size of the precipitates mainly of $\text{Ti}_4\text{C}_2\text{S}_2$ also contains TiS in addition to the $\text{Ti}_4\text{C}_2\text{S}_2$, and the size of the precipitates is 1,000 to 10,000Å with preferably a count of 5×10^5 pcs/mm².

While said hot rolled steel or cold rolled steel can now be utilized as it is, the surface can be galvanized to improve the corrosion resistance and outer appearance. In this invention, this process includes formation of 3 to 4 g/m² of zinc galvanized layer on at least one side of the hot rolled steel or the cold rolled steel sheet, and then further forming a plastic coating of 1 to 2.5 g/m² on the zinc galvanized layer of the steel. This plastic coating

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of the steel serves to further improve the corrosion resistance and the resistance to fingerprints.

This invention is also characterized by manufacturing methods for the cold rolled steel and hot rolled steel sheets. In the preferred makeup of the hot rolled steel manufacturing method, composition of the said elements for the hot rolled steel sheet conditions are satisfied and further, the value calculated from said $(Ti^*/48)/(C/12 + S/32)$ is within a range of 1.0 to 3.0, and after the steel has been heated within a temperature range of 1,100 to 1,200°C, heat form rolling is completed within the temperature range (Ar₃ transformation temp. +80°C) to (Ar₃ transformation temp. -40°C) next, coiling at a temperature range below 700°C produces precipitates comprised internally mainly of Ti₄C₂S₂, with a size of 1,000 to 10,000Å and a count of 5×10^3 pcs/mm².

The preferred version of the cold rolled steel manufacturing method is characterized by, a chemical composition satisfying said elements listed previously and further, the value calculated from said $(Ti^*/48)/(C/12 + S/32)$ is within a range of 0.8 to 4.0. After the steel has been heated within a temperature range of 1,100 to 1,200°C, heat form rolling is completed within the temperature range (Ar₃ transformation temp. +80°C) to (Ar₃ transformation temp. -40°C). Coiling at a temperature range between 600 to 700°C is then performed, and after cold rolling of the steel, annealing is carried out to produce a precipitates

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comprised internally mainly of $Ti_4C_2S_2$, with a size of 1,000 to 10,000Å and a count of 1×10^4 to 5×10^5 pcs/mm².

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph showing the effect of sulfur content in the steel on burr height and the r value during punch processability.

Fig. 2 is a graph showing the relation of sulfur content in the steel to surface flaw generation index.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As described above, the steel (hereafter including both cold rolled steel and hot rolled steel) of this invention, along with having specific constituents in the steel, internally comprises precipitates mainly of $Ti_4C_2S_2$, or $Ti_4C_2S_2$ and TiS , with said precipitates preferably having a specified size and amount. These conditions which are basically similar to the composition of the conventional super low carbon IF steel allow superior press characteristics to be maintained and succeed in attaining a substantial improvement in punch and machining characteristics.

More specifically, by keeping the sulfur content to a minimum to improve punch processability, the sulfur is formed into precipitates mainly of $Ti_4C_2S_2$, or $Ti_4C_2S_2$ and TiS , by preferably regulating the size and amount of this precipitates the defects pointed out in the examples of the conventional art are avoided and a steel with superior

forming and punching processing and also with satisfactory flange processing and stretch-flangeability in later processes can be obtained. In order to guarantee this superior punch processability, the burr height after punch processability should be less than 25 μm and more preferably less than 15 μm .

Normally, press and punch processability is performed at room temperatures and the material temperature is not raised substantially, because obtaining said improved results in terms of condition, size and dispersion of the precipitates and inclusions requires processing at room temperature. Also, during machining the temperature is quite high so that the inclusion in the material must be of a type able to provide the desired material machining characteristics by fusing (of the inclusion) in the temperature range occurring during machining. The precipitates composed mainly of $\text{Ti}_4\text{C}_2\text{S}_2$ is provided with all of these characteristics and a large improvement in machining such as punch processability has been verified. The TiS precipitates are large compared to the $\text{Ti}_4\text{C}_2\text{S}_2$ material and can cause surface defects but when the size is within a range of 1,000 to 10,000 $\text{\AA}$, such surface defects do not occur and the improved machining and punch processability characteristics were confirmed to be the same as those for the $\text{Ti}_4\text{C}_2\text{S}_2$ material.

When observing the punched steel sheet on the microscopic level however, it seems that a sheared surface is first formed on the front and back of the steel sheet



accompanying the contact of the falling punch with the steel sheet. The concentrated stress on said sheared surface causes strong shear deformation resulting in formation of voids which in turn form cracks which grow larger on the front and back of the sheet and when these cracks join together the punched steel is obtained. Therefore promoting development of the above mentioned voids and cracks should prove effective in reducing the size of burrs after punch processability. In the $Ti_4C_2S_2$ and TiS however, the precipitates is relatively large so that development of cracks and voids can progress in the vicinity of the strong shear deformation. Consequently punch processability is remarkably improved and the size of burrs is also reduced.

In stretch-flangeability on the other hand, the edges of the hole formed by punching are widened in so-called "flange up" processing by means of conic or cylindrical punches. The voids formed at the boundaries join and become cracks, piercing through the sheet. Therefore it is preferable to reduce the amount of precipitates and inclusions which promotes forming of these voids and cracks.

As can be seen, different effects are exerted on the punching and burring characteristics by the size of the precipitates and inclusions. Research by the inventors as related below, confirms that among the various precipitates and inclusions, if the size and dispersion amounts in particular of the $Ti_4C_2S_2$ or the $Ti_4C_2S_2$ and TiS are

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controlled in optimal amounts, the dual goals of punch processability and stretch-flangeability can be achieved without surface defects.

Also the precipitates and inclusions in the super-low carbon IF steel, other than MnS and Al_2O_3 which are normally included in steel, also comprise titanium additives such as TiC, $Ti_4C_2S_2$, TiS, TiN, FeTiP, Ti_2O ; and Nb(C,N) in steel with niobium additives. These have their own special characteristics relative to respective sizes and distributions and the following pertinent information has been verified after observing the effects on the formability, machinability, punching and burring characteristics of the steel.

$Ti_4C_2S_2$, TiS:

If the size of $Ti_4C_2S_2$ precipitates is 1,000 to 10,000Å, and the quantity for hot rolled steel is 5×10^3 pcs/mm² or more, and for cold rolled steel is within 1×10^4 to 5×10^5 pcs/mm², then not only will the machinability and punch processability be remarkably improved but there will be virtually no adverse effects on formability for burrs etc. The above difference in allowable quantity between hot and cold rolled steel is due to the high surface precision required of cold rolled steel. This limit was established for the cold rolled steel due to the possibility of excessive amounts of said precipitates adversely affecting the surface precision. A slab of steel satisfying conditions later related for the

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constituents of the precipitates mainly comprising $Ti_4C_2S_2$ was heated within a temperature range of 1,100 to 1,200°C and then heat form rolling completed within the temperature range (Ar_3 transformation temp. +80°C) to (Ar_3 transformation temp. -40°C). For hot rolled steel the material was next wound up at a temperature range below 700°C. For cold rolled steel however, the coiling was performed within a range set at 600 to 700°C after heat rolling and after next performing cold rolling by the usual method, annealing was carried out in an efficient process. During heating of the above slab, TiS may precipitate during final stages of $Ti_4C_2S_2$ generation. The size of the TiS material at completion of heat rolling is considerably large compared to that of the $Ti_4C_2S_2$ material so that surface defects may possibly occur when used in heat rolling. Therefore when actually using the steel, conditions must be set to limit the TiS precipitates as much as possible.

However in the cold rolling performed after the hot rolling, this large TiS precipitates break up into fine pieces in the cold rolling process and almost no growth of the TiS precipitates occur in the later annealing process so improved punch processability is maintained and adverse effects leading to surface defects are eliminated so that virtually the same effects as the $Ti_4C_2S_2$ material are displayed. Therefore when using as cold rolled steel which includes TiS in the precipitates mainly of $Ti_4C_2S_2$, a remarkable improvement in the punch processability can be

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achieved if the size of the precipitates is kept within 1,000 to 10,000Å and the amount is kept within 1×10^4 to 5×10^5 pcs/mm².

Further, deviations from the preferred conditions for heating temperatures and hot rolling will reduce the quantity of precipitates comprising mainly Ti₄C₂S₂ or Ti₄C₂S₂ and TiS so that not only is a poor improvement shown for punch processability and stretch-flangeability but TiC is produced which causes adverse effects on steel forming and the object of this invention cannot be achieved.

TiC, Nb (C,N):

When the precipitates are approximately 100Å, the size is too small so that not only is an adverse effect wrought on the steel forming, but the improvement in punch processability is poor. A process is known (Japanese Patent Laid-open No. Hei 6-73457) for improving the punch processability and forming in super-low carbon IF steel by adding a compound of titanium and niobium to the cold rolled steel. However, evaluation by the inventors confirmed that addition of niobium within a range of 0.003 to 0.03% in the steel generated Nb(C,N) in the steel and consumed the carbon with the result that the Ti₄C₂S₂ effective in improving the punch processability and stretch-flangeability was not produced and the object of the invention could not be achieved.

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**FeTiP:**

As precipitates FeTiP have a size approximating that of $Ti_4C_2S_2$ and is effective in improving punch processability and stretch-flangeability however a film precipitate occurs on the crystal boundaries so that steel forming becomes drastically worse.

TiN:

As precipitates TiN have a size approximating that of $Ti_4C_2S_2$ and achieves equivalent improved results however it is too soft in actual use and shows almost no improvement in punch processability and poor improvement in stretch-flangeability effects. Furthermore, the machining is unsatisfactory since a rise in temperature during machining degrades the cutting effect. The nitrogen content is also difficult to regulate, so that effective improvements in machining, punching and stretch-flangeability of steel with these Ti compounds is difficult to achieve.

Ti₂O:

The size of the precipitates is on a larger scale than $Ti_4C_2S_2$, with poor improvement in punch processability and stretch-flangeability. Furthermore Ti_2O is not desirable because of possible surface defects.

MnS:

MnS has inclusions and precipitates with the former being in micron units and the latter being 1/10th of that



size. When the sulfur increases the increased inclusion mass means that punch processability is improved but as shown in the previously mentioned Japanese Patent Laid-open No. Hei 6-73457 an improved punch processability requires 0.02% or more of sulfur. A large quantity of sulfur can cause poor forming and surface defects.

As shown above there are many possible combination of compounds for obtaining and producing inclusions and precipitates in the IF-based steel sheet containing super-low carbon titanium. Among these various compounds, $Ti_4C_2S_2$ having a precipitate size of 1,000 to 10,000Å or ($Ti_4C_2S_2$ and TiS) brings out favorable effects on punching and stretch-flangeability without causing adverse effects on forming. Furthermore if the steel sheet constituents and machining conditions are suitably adjusted so that; the precipitates mainly composed of the $Ti_4C_2S_2$ or ($Ti_4C_2S_2$ and TiS) in amounts of 5×10^3 pcs/mm² or more for hot rolled steel sheet, and on the other hand, kept within a range of 1×10^4 to 5×10^5 pcs/mm² for cold rolled steel then the features can be demonstrated in an extremely effective manner. This new knowledge became the basis for the present invention. Next, the reason for setting the chemical constituents of the steel sheet of this invention are clarified.

C : 0.0010 to 0.010%

Carbon combines with titanium to produce $Ti_4C_2S_2$ and is an indispensable element. The carbon content must be at



least 0.0010%, however if the carbon content is too large, the amount of TiC produced increases and along with a decrease in the ductility or elongation of the metal, the yield stress rises and the forming and stretch-flangeability are adversely affected. In view of these facts an upper limit of 0.010% was set to ensure good forming.

Si : 1.0% or less

Silicon is an effective element for improving strength without loss of ductility or elongation but when the silicon content is too high, the oxidized layer produced during annealing grows large and exerts adverse effects on later forming processes also causing uneven distribution of the galvanized layer. Due to these reasons the silicon content is limited to 1.00% or less. Further, non-galvanized portion are prone to occur during alloy fusion galvanizing of the steel sheet due to the forming of said oxidized layer so the silicon content should preferably be restricted to 0.20%.

Mn: 0.1 to 1.0%

Manganese produces MnS and is an auxiliary element for improved stretch-flangeability and punch processability. The manganese content must be 0.10% or more to effectively demonstrate these improvements. However when the content is too large an adverse effect is wrought on the forming

and stretch-flangeability so manganese content must be limited to 1% or less.

P: 0.1% or less

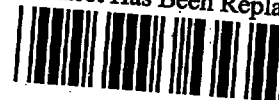
Phosphorus is suspended in the steel or forms FeTiP precipitates. In the former case phosphorus is a strengthening element and conversely exerts adverse effects on the forming. In the latter case on becoming precipitates, the punching and stretch-flangeability were found to be somewhat improved but the effect on forming was extremely bad so that phosphorus should be limited to 0.1% or less and preferably to 0.05% or less.

S: 0.01 to 0.025%

Sulfur combines with the later related Ti and is an indispensable element in forming precipitates comprising mainly $\text{Ti}_4\text{C}_2\text{S}_2$ or ($\text{Ti}_4\text{C}_2\text{S}_2$ and TiS). In order for these precipitates to show improved punch processability, the $\text{Ti}_4\text{C}_2\text{S}_2$ or ($\text{Ti}_4\text{C}_2\text{S}_2$ and TiS) must be in amounts of 5×10^3 pcs/mm² or more. The sulfur content must therefore be 0.010% or more. However these effects are maximized at 0.025% and when the content is excessive, not only are adverse effects exerted on the press forming but surface defects are prone to increase so the upper limit is set at 0.025%.

Incidentally, Figure 1 is a graph showing the punch processability and r value when the sulfur content is made to change from 0.002% to 0.037%, for steel sheet with a





basic composition of 0.0052% carbon, 0.01% silicon, 0.4% manganese, 0.014% phosphor, 0.03% aluminum, 0.08% titanium and 0.006% nitrogen. In the figure, box annealed type A1 killed steel (C: 0.044%, Al: 0.045%) having superior punching and mechanical characteristics is used as the comparison sample. Fig. 2 shows the sulfur content versus the percentage of surface defects.

The physical properties test was performed as follows. A vacuum dissolved, forged 40 kg metal ingot was heated to 1200°C and the rough rolled at 30 mm^t. Next, after heating this slab to 1200°C, it was hot rolled under conditions of plate thickness of 4 mm^t, finish temperature of 920°C or more, roll temperature of 680°C and then cut to 3.2 mm^t. Afterwards the metal was cold rolled to 0.8 mm^t and after consecutive annealing for 1 minute at an average temperature of 800°C, a 1% rolling adjustment was performed to produce the test sample cold-rolled sheet. A 10 mm x 110 mm test sample was utilized for the r value, and the width and sheet thickness measured when a tensile strain of 0 to 15% was applied. The burr height was measured and evaluated at the edges after punching a circular shape of 10 mm diameter in 0.8 mm^t cold rolled steel with a clearance of 9%. The surface of the cold rolled steel sheet was examined visually for surface defects and evaluated by finding the percent of surface defects occurring in a fixed length.

As Figs. 1 and 2 clearly show, when the sulfur content is less than 0.01% the burr height during punching is



extremely large and the object of this invention cannot be achieved. However when the sulfur content exceeds 0.025%, surface defects drastically increase again thwarting the object of the invention. However when the sulfur content is 0.01% or more, and 0.025% or less, the surface defects and burr height can be limited as much as possible and a high level r value can be obtained.

The data in Figs. 1 and 2 shows the effect the sulfur content exerts on physical characteristics of the cold rolled steel. This effect is largely the same as that for the hot rolled steel before cold rolling was performed. Setting the sulfur content within a range of 0.001 to 0.025% was verified as yielding hot rolled steel sheet with superior punch processability and no surface defects.

N: 0.01% or less

Nitrogen combines with titanium to produce TiN but this TiN has virtually no effect in improving punch processability. Nitrogen, as is the case with carbon, weakens the stretch-flangeability and tensile properties of the steel and therefore an upper limit of 0.01% was set to avoid these drawbacks.

Ti: 0.2% or less

Titanium is one of the most important elements because of the $Ti_4C_2S_2$ or ($Ti_4C_2S_2$ and TiS) precipitates produced in the steel and the improvement provided in punch processability and stretch-flangeability. The lower limit



value for titanium content must be determined according to the nitrogen, sulfur and carbon content in the steel. However a maximum content achieving the effect of the invention is 0.2%, a higher content would not be cost effective. Preferably the titanium content is 0.15% or less.

Besides forming $Ti_4C_2S_2$ and TiS , titanium can also according to conditions form with nitrogen in solid solution to produce TiN , or with carbon in solid solution to produce TiC . The lower limit value of titanium must be determined by taking into account their respective effects and according to the carbon, sulfur and nitrogen content based on formula (1) below. When forming hot rolled steel this value should be in the range of 1.0 to 3.0 and for cold rolled steel should be in the range of 0.8 to 4.0 with the content of each element adjusted according to the relation with the other element.

$$(Ti^*/48)/(C/12 + S/32) \quad \text{----- Formula (1)}$$

$$\text{However, } Ti^* = Ti - (48/14)N$$

However, for hot rolled steel, when the value is less than that in formula 1, the amount of titanium is insufficient for bonding with the carbon and sulfur and the amount is insufficient for producing $Ti_4C_2S_2$ needed for improving the punch processability. However when the value exceeds 3.0 and the carbon content is excessive, the amount of carbon in solid solution increases, or when the sulfur content is excessive, MnS and large TiS is produced so that in either of these cases the ductility or elongation is



poor and insufficient forming and stretch-flangeability processing are obtained. In cold rolled steel, when the value from the above formula (1) is less than 0.8, the amount of titanium for bonding with the carbon and sulfur is insufficient and the amount of $Ti_4C_2S_2$ needed for improving the punch processability is inadequate. However when this value exceeds 4.0 and the carbon content is excessive, then the carbon in solid solution will increase, or when the sulfur is excessive, MnS is produced so that in either of these cases the ductility or elongation is poor and insufficient forming and stretch-flangeability processing are obtained. In the case of cold rolled steel, there is some tolerance allowed in the value obtained from formula (1) because at the end of hot rolling performed prior to the cold rolling, even if some large (rough) TiS is produced, the subsequent cold rolling will break down the TiS into finer particles so there will be no significant problem due to effects on surface precision.

Al: 0.1% or less

Aluminum is an element whose use is essential and unavoidable as an antioxidant. Too high an aluminum content is a source for non-metallic Al_2O_3 based inclusions which exerts adverse effects on mechanical characteristics and machining so that aluminum content is limited to 0.1% or less.

When the steel sheet of this invention having a precipitates constituting mainly $Ti_4C_2S_2$ (or $Ti_4C_2S_2$ and



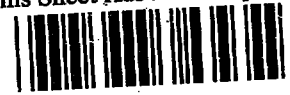
TiS) and a size within a range of 1,000 to 10,000Å is included in specific proportions in the steel, the machining , punching and stretch-flangeability are improved remarkably with no adverse effects on forming. However the steel sheet manufacturing conditions, and further the temperature during heat rolling and coiling conditions are essential in producing the optimal amounts of this precipitate of mainly $Ti_4C_2S_2$ in the steel. It has been confirmed that to attain the object of the invention, it will prove sufficient to heat a steel slab that satisfies the above mentioned requirements for chemical constituents, to within a range of 1,100 to 1,200°C, complete heat form rolling within the temperature range (Ar_3 transformation temp. +80°C) to (Ar_3 transformation temp. -40°C), followed by coiling at a temperature range between 600 to 700°C.

If the heating temperature at this time is below 1,100°C, then the amount of MnS produced increases and the amount of $Ti_4C_2S_2$ precipitates in the steel will be inadequate. If the heat exceeds 1,200°C virtually all of the precipitates dissolves and the correct amount of $Ti_4C_2S_2$ precipitates cannot be obtained. Also, when the temperature during heat form rolling exceeds 700°C, the $Ti_4C_2S_2$ based precipitates changes into FeTiP based precipitates and the improved machinability and punch processability desired of this invention cannot be obtained. No particular value is set as a lower limit for the coiling temperature but if too low then Ti based precipitates is not produced or even if produced the TiC as



$\text{Ti}_4\text{C}_2\text{S}_2$ precipitates cannot be obtained, so that a temperature of 500°C or higher is preferable. If the coiling temperature is too low when manufacturing cold rolled steel sheet, then the TiC precipitate will be incomplete and a residual amount of carbon in solid solution will cause the r value for annealing to deteriorate, so that the coiling temperature is preferably set within a range of 600 to 700°C .

As long as the above heating temperatures and coiling temperatures are maintained, there will be little effect on the amount of $\text{Ti}_4\text{C}_2\text{S}_2$ produced even if the heat roll finishing temperature varies somewhat. However, in order to achieve both smooth heat rolling and heat rolled steel sheet having stable mechanical characteristics and product shape, the finishing temperature is preferably set within a range of (Ar_3 transformation temp. $+80^\circ\text{C}$) to (Ar_3 transformation temp. -40°C). However when the heat roll finishing temperature is too low, FeTiP is produced. This FeTiP and the carbon in solid solution causes the press-forming characteristics to worsen. Conversely, when the heat roll finishing temperature is too high, the amount of large (rough) TiS produced increases which in particular can be a source of surface defects during use of the hot rolled steel sheet. However, when this is cold rolled and used as cold rolled steel sheet, the above mentioned large (rough) TiS is broken down into finer pieces in the cold rolling process and thus will not be a source of surface defects. These TiS precipitates are an effective



constituent for improving the punch processability when making actual use of the cold rolled steel sheet.

There are no particular limits on the conditions for cold rolling and annealing performed after the heat rolling however, a preferred size and dispersion amount of $Ti_4C_2S_2$ precipitates produced in the heat rolling process for maintaining the desired effects is a downward pressure setting of 60 to 85% and a temperature of 700°C or more and the Ac_3 point or below in the later annealing process, with a temperature range setting of 750 to 850°C being even more preferable. If the above mentioned downward pressure setting is used for cold rolling, even if the large (rough) TiS based precipitates is present internally after completion of hot rolling, these precipitates will be broken down into finer pieces in the cold rolling process and thus will not be a source of surface defects and the precipitates will prove an effective element in obtaining improved punch processability.

The hot rolled steel sheet or cold rolled steel sheet thus obtained may be used as is, or further electrically galvanized or fused zinc galvanized for anti-rust purposes, or chemical processing such as acid-base processing or chromate processing performed. Additionally, organic plastic coating or similar processing will of course prove effective as surface treatments.

There are few cases of a steel plate chassis actually being used without having some kind of surface coating. This is because use of cold or hot rolled steel sheet as



is, generates red rust in a short time in the outside atmosphere. This rust eats into the metal not only reducing its strength but exerting adverse effects on the drive sections and electrical circuitry due to loose rust powder. Use of a surface treatment is an extremely effective method in preventing the generation of rust. This invention utilizes zinc alloy electrical galvanizing which displays a superior effect in preventing rust without exerting adverse effects on the forming and punch processability.

Various galvanizing methods are available such as fusible galvanizing performed by soaking the steel sheet in fusible zinc in solution, electrical galvanizing for precipitateing metallic zinc on the steel sheet surface by applying a charge through electrolytic fluid containing zinc ions, and the steam adhesion galvanizing method for making zinc in a vaporized state adhere to the surface of the steel sheet. However, in this invention utilization of the electrical galvanizing method is desirable because of the fine appearance and even distribution of material in the galvanized layer along with the fact that there are no surface defects even though the material adhering is relatively thin. In order for this electrically galvanized layer to be effective in preventing rust, the galvanized layer should adhere in a thickness of 3 g/m² or more. If this adhering layer is insufficient then anti-corrosion properties cannot be guaranteed or the plastic coating formed over the galvanized layer must be made excessively



thick and the electrical grounding property is lost. From the viewpoint of corrosion resistance there is no particular limit on the adhering galvanized layer thickness but when it exceeds 40 g/m^2 an anti-corrosive effect may not be obtained even if the layer is made excessively thick. If the galvanizing process time is too long or the sealing of the galvanized layer is too low then peeling of this layer may occur so it should be limited to a thickness of 40 g/m^2 .

The zinc electrically galvanized layer used here, besides pure zinc galvanizing also includes zinc-based galvanizing containing Ni, Co and Fe along with the zinc, or may be a lower coating of this same pure zinc galvanizing or zinc-based galvanizing or perhaps a different type of pre-galvanizing, in zinc galvanizing types where the zinc content is 50% or more by weight.

Forming of the zinc electrically galvanized layer is by itself, sufficient to obtain the objective of anti-rust in the steel plate. To use this as a material for items such as chassis, resistance to fingerprints is preferable in addition to preventing rust on the galvanized layer itself. An extremely effective method to achieve this is to further apply a plastic coating over the zinc electrically galvanized layer. The preferred adherence amount for the plastic coating is within a range of 0.1 to 2.5 g/m^2 . When the amount of plastic coating that adheres is insufficient, satisfactory corrosion resistance and fingerprint resistance cannot be obtained. Conversely when



the amount is too large, the electrical conductivity of the top layer decreases and the grounding is extremely poor.

There are no particular limits on the constituent types of the resin composing the plastic layer but most typically these are ethylene polymer resin, polyester resin, polyvinyl resin, acrylic resin, urethane resin, or polyamide resin containing polymers of epoxy resin or ethylene non-saturated carboxylic acid. These resin types can be used alone or mixed from two or more types as needed. Forming favorable resin constituents is recommended by altering the functional groups within these resins by the usual methods or reinforcing them with cross-link solution. Furthermore, organic or inorganic silicon compounds can be applied for instance to improve resistance to fingerprints, or wax constituents can be added to the resin in small amounts to improve surface type scuffing characteristics during press processing, or wax constituents can be introduced in reformed elements in functional groups in the resin.

The plastic coating is preferable as a protective surface layer after press processing for providing resistance to corrosion and resistance to fingerprints. For this purpose a resin mix of one or more types of epoxy resin, ethylene polymer resin, polyester resin, and urethane resin are preferable as base resins.

Preferably the anti-corrosiveness of the plastic coating is further improved adding for instance silica particles such as of silicon inorganic compounds in an



amount of approximately 5% or more by weight to the base resin. However when the silica particle content is too large, it functions as an anti-slip material, raising the friction index of the coating and lowering its lubricating qualities. A further drawback is a decrease in resistance to corrosion that appears after machining so that the content should be about 30% or less by weight, or more preferably 10% or less by weight.

The effect from these silica particles is best obtained by using a particle size of 1 to 20 μm . In other words, the smaller the silica particles the finer the coating becomes and the sealing thus improves. Consequently the corrosion resistance of the coating and coatability (layer precipitation) improves, however if the particles smaller than 1 μm are used, a still greater effect may not be achieved, so that a lower particle size limit of 1 μm is sufficient. Conversely, when the size exceeds 20 μm , the surface of the coating is rough, a fine membrane cannot be formed, and the resistance to corrosion is also poor. Thus a preferable particle size is 4 to 6 μm . This kind of silica particle is known as colloidal silica and is commercially obtainable for instance under the brand name "Snow-Tex XS or Snow-Tex SS" (both manufactured by Nissan Kagaku Kogyo : commercial name).

There are no limits whatsoever on the method for forming the plastic coating. After forming an electrical galvanized layer by the usual methods on one side or both sides of the hot rolled steel sheet or the cold rolled



steel sheet manufactured by a method as related previously, the plastic coating may be applied over the galvanized surface by the desired method such as roll coating, dip coating or spray coating. After performing chemical treatment such as chromate processing or acid-base processing of the surface of the galvanized steel sheet, forming of the plastic layer at this time will prove effective in enhancing the sealing of the galvanized layer with the plastic coating which is of course included within the technical scope of this invention.

EXAMPLES:

Specific examples of the structure and effect of the invention are described in the embodiments listed here yet this invention is not limited by the embodiments described hereafter and may be further changed as appropriate within the applicable spirit of the invention and the foregoing is included within the technical scope of this invention.

The performance tests employed in the following embodiments, for the tensile properties, machinability, punch processability and verification methods for the type and amount of precipitates in the steel plate are described below.

Verification of type and amount of precipitates:

Observation was performed by the replica extraction method using a transparency type electron microscope. At 10,000 times magnification, the amount of the precipitates was



found within a visual range of 0.15 mm^2 and this then counted to obtain the precipitates amount within 1 mm^2 .

Tensile properties:

A test piece setup for JIS5 was used in the tensile tests. The yield point (YP), tensile strength (TS), elongation (El) and work hardening coefficient (n value) were each evaluated. After further processing at 100°C for 60 minutes, non-aging properties (A.I) was evaluated from the amount of rise in the yield point.

r value:

A test piece of $10 \text{ mm} \times 110 \text{ mm}$ was utilized. The width and thickness of the piece was measured when a tensile strain of 0% and 15% was applied.

Punch Processability:

A circular pattern with a clearance of approximately 12% and diameter of 30 mm was punched and the height of the burrs occurring on the edge were measured and evaluated.

Machinability:

A pipe with an outer diameter of 60 mm was fabricated utilizing the high frequency induction heat welding method for each test piece sheet. Cutting was carried out at a cutting speed of 125 m/minute, and notching speed of 0.06 m/revolution. The cut-through repetitions (for tool life) and swarf (cutting waste) status (GOOD = small, curl-shaped swarf, DEFECT = long curl-shaped swarf) were evaluated.

Stretch-flanging:

A hole 20 mm in diameter was punched in each test piece sheet. The punched hole (dia./mm) was widened with a conical punch at an apex angle of 30 degrees until the crack penetrated through the sheet thickness. The hole expansion rate was found by means of the formula below, from the hole diameter (df:mm) at that time, and the stretch-flangeability evaluated.

$$\text{Hole expansion rate} = [(df-di) / di] \times 100 (\%)$$

First Embodiment

After heating the steel slab with the chemical compositions shown in Table 1, to 1180°C, a hot rolling finishing temperature of approximately 920°C and a coiling temperature of 630°C was set, and hot rolling performed to obtain hot rolled steel sheet with a thickness of 3.2 mm.

The precipitates type and amount produced in the steel obtained from the hot rolling was investigated along with the tensile properties, machinability and punch processability. The results are shown in Table 2.

This Sheet Has Been Replaced



Table 1

Steel type	Chemical compositions (mass%)									Ar3 point	Precipitates figure*1 (piece/mm ²)	Re-marks
	C	Si	Mn	P	S	Al	Ti	N	(Ti*/48) /(C/12+S/32)			
A	0.0052	0.02	0.32	0.013	0.017	0.032	0.078	0.0067	1.2	892	2.1×10 ⁴	*2
B	0.0031	0.02	0.46	0.035	0.014	0.033	0.048	0.0027	1.2	877	1.6×10 ⁴	*2
C	0.0033	0.01	0.63	0.015	0.022	0.033	0.070	0.0028	1.3	865	3.7×10 ⁴	*2
D	0.0032	0.01	0.94	0.016	0.018	0.034	0.076	0.0036	1.6	857	4.2×10 ⁴	*2
E	0.0129	0.02	0.37	0.016	0.008	0.032	0.115	0.0059	1.5	883	3.9×10 ³	*3
F	0.0017	0.44	0.44	0.091	0.007	0.031	0.085	0.0041	4.1	874	3.2×10 ³	*3
G	0.0044	0.02	0.17	0.016	0.009	0.028	0.076	0.0045	2.0	905	2.3×10 ³	*3
H	0.0035	0.01	1.15	0.014	0.006	0.031	0.066	0.0037	2.3	825	2.7×10 ³	*3
I	0.0032	0.01	0.44	0.088	0.008	0.036	0.074	0.0108	1.5	881	4.1×10 ⁴	*3
J	0.0028	0.02	0.46	0.013	0.005	0.036	0.039	0.0034	1.4	868	2.8×10 ⁴	*3
K	0.0045	0.01	0.44	0.018	0.031	0.029	0.106	0.0045	1.4	876	2.3×10 ⁵	*3
L	0.0055	0.01	0.42	0.015	0.016	0.031	0.055	0.0056	0.8	875	2.4×10 ⁴	*3
M	0.0007	0.01	0.45	0.021	0.022	0.035	0.077	0.0032	1.8	879	3.1×10 ³	*3

- *1: Quantity of precipitates with size of 1000 to 10000Å.
Steel types F and I have precipitates of FeTiP alloy
and the other steel types are Ti₄C₂S₂ type alloy.
- *2: Example of the present invention.
- *3: Comparison example.

This Sheet Has Been Replaced





Table 2

Steel type	Tensile properties				Punching characteristics	Machinability		Remarks
	YS (N/mm ²)	TS (N/mm ²)	n value	E1 (%)	Burr height (μm)	Tool life (times)	Cutting grit disposal	
A	163	315	0.247	53	34	56	o	*1
B	158	324	0.251	53	24	53	o	*1
C	159	328	0.242	52	29	48	o	*1
D	190	385	0.236	45	25	46	o	*1
E	184	342	0.222	45	44	37	x	*2
F	224	436	0.203	36	38	29	x	*2
G	162	318	0.242	50	65	39	x	*2
H	214	355	0.222	45	54	41	x	*2
I	221	359	0.219	44	46	26	x	*2
J	153	317	0.244	49	57	17	x	*2
K	164	323	0.231	46	37	43	o	*2
L	190	314	0.196	45	40	45	o	*2
M	143	297	0.250	51	63	21	x	*2

*1: Example of the present invention

*2: Comparison example

Results from Tables 1 and 2 can be interpreted as follows.

Steel types A, B and C are soft steel while steel type D is high strength steel that satisfy the stipulated conditions for this invention. All of these types, along with having superior tensile properties also provide superior performance for punching and machining .



In contrast, steel types E through J all had poor punch processability and machinability due to an insufficient sulfur content. In addition, the steel type E has too high a carbon content so tensile properties are poor because TiC is produced. The steel type H had too high a manganese content so punch processability was poor because MnS is produced. The steel type M had an insufficient amount of carbon so that tensile properties are poor and further has poor punch processability because an inadequate amount of $Ti_4C_2S_2$ precipitates is produced. The following is not shown in Table 2 however, because the silicon content in steel type F is too large, a silicon oxide layer during the electrical galvanizing caused variations in the galvanized layer and the sealing of the galvanized layer was poor. In steel type K it was verified that, because the sulfur content was too large, the tensile properties were bad even though the punch processability was satisfactory, furthermore surface defects such as blisters and slivers were verified on the steel sheet surface after rolling. In steel types F and L, the balance between the amount of Ti and the amount of carbon and steel was poor, so that the conditions in the above mentioned formula (1) could not be satisfied. Consequently besides the tensile properties balance being bad, the punch processability was poor and the resistance to aging unsatisfactory.

Second Embodiment



The steel type B (877°C at Ar₃ point) shown in Table 1 was utilized. The hot form rolling was performed in the same way as for the first embodiment except for the heating temperature, finishing temperature and coiling temperature which were changed as shown in Table 3. The hot rolled steel sheet was manufactured to a width of 3.2 mm. Along with investigating the precipitates types and amount for each test piece exactly as in the first embodiment, along with the tensile properties, and punch processability. The results are shown in Table 4.

Table 3

Steel type	Hot rolling condition (°C)			Precipitates figure and status (piece/mm ²)	Remarks
	Heating temp.	Finishing temp.	Coiling temp.		
B1	1230	935	610	3.4×10 ³ TiS type	*1
B2	1180	920	630	1.6×10 ⁴ Ti ₄ C ₂ S ₂ type	*2
B3	1145	915	620	1.0×10 ⁴ Ti ₄ C ₂ S ₂ type	*2
B4	1070	930	605	4.7×10 ³ MnS type	*1
B5	1175	995	630	3.5×10 ³ MnS type	*1
B6	1170	895	630	3.6×10 ⁴ Ti ₄ C ₂ S ₂ type	*2
B7	1180	825	625	2.7×10 ³ FeTiP type	*1
B8	1190	915	735	3.8×10 ³ FeTiP type	*1
B9	1175	930	580	1.9×10 ⁴ Ti ₄ C ₂ S ₂ type	*2
B10	1185	920	525	4.4×10 ⁴ Ti ₄ C ₂ S ₂ type	*2

*1: Comparison example

*2: Example of the present invention



Table 4

Steel type	Tensile properties				Punching characteristics	Machinability		Remarks
	YS (N/mm ²)	TS (N/mm ²)	n value	E1 (%)	Burr height (μm)	Tool life (times)	Cutting grit disposal	
B1	163	327	0.249	51	44	46	×	*1
B2	158	324	0.251	53	24	53	○	*2
B3	157	325	0.247	52	27	49	○	*2
B4	155	319	0.244	49	41	37	×	*1
B5	149	324	0.213	47	43	38	×	*1
B6	159	322	0.254	53	26	55	○	*2
B7	154	317	0.196	43	32	46	Δ	*1
B8	162	320	0.218	47	38	30	×	*1
B9	153	328	0.246	43	31	50	○	*2
B10	166	336	0.237	48	35	44	○	*2

*1: Comparison example

*2: Example of the present invention

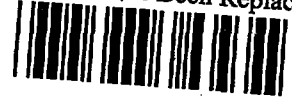
The symbols B₁ through B₄ in Tables 3 and 4 show the suitable temperature ranges for the hot roll finishing temperature and coiling temperature. In particular, when investigating the effect of the heating temperature, it was found in steel types where heating was performed in a range from 1,100 to 1,200°C (symbols B₂, B₃) that Ti₄C₂S₂ based precipitates was produced in suitable sizes and amounts and the tensile properties and punch processability were superior in each case. In contrast, when the heating temperature in the comparison sample (symbol B₁) exceeded



1,200°C, precipitates mainly of Tis were formed, and when the temperature dropped below 1,100°C in the comparison sample (symbol B₄) a precipitate mainly of MnS was formed with the punch processability and machinability being poor in both cases.

The symbols B₅ through B₇ show the suitable temperature ranges for heating temperature and coiling temperature. In particular, when investigating the effect of finishing temperature, it was found that in steel types where heating was performed in a range from 1,100 to 1,200°C (symbols B₆) Ti₄C₂S₂ based precipitate was produced in suitable sizes and amounts and the tensile properties and punch processability were superior in each case. In contrast, when finishing temperature in the comparison sample (symbol B₅) was too high, precipitates mainly of MnS were formed, and when finishing temperature was too low in the comparison sample (symbol B₇) precipitates mainly of FeTiP were formed with the punch processability being poor in both cases.

The symbols B₈ through B₁₀ show the suitable temperature ranges for heating temperature and the finishing temperatures. In particular, when investigating the effect of the coiling temperature, it was found that in steel types where the coiling temperature was in the correct range (symbols B₁₀, B₁₁) Ti₄C₂S₂ based precipitates was produced in suitable sizes and amounts and the tensile properties and punch processability were superior in each case. In contrast, when the coiling temperature in the



comparison sample (symbol B8) was too high, precipitates mainly of FeTiP were formed and satisfactory machinability could not be obtained.

Third Embodiment

After steel slab with the chemical compositions shown in Table 5 was heated to 1180°C, a finishing temperature of approximately 920°C and a coiling temperature of 630°C was set, and hot rolling then performed. After obtaining hot rolled steel with a thickness of 3.2 mm, each hot rolled steel sheet was then cold rolled to a thickness of 0.8 mm. After performing consecutive annealing for 1 minute at 800°C, 1 percent temper rolling was carried out. The respective tensile properties and punch processability were investigated and the results obtained are given in Table 5.

Along with investigating the precipitates types and amounts produced in the cold rolled steel obtained above, the tensile properties, punch processability, and stretch-flangeability were also investigated and the results obtained are shown in Table 6.

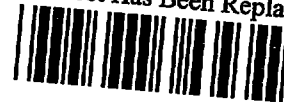


Table 5

type	Chemical compositions (mass%)										Ar ₃ point	Precipitates figure ^{*1} (piece/mm ²)	Re-marks
	C	Si	Mn	P	S	Al	Ti	N	B	(Ti*/48) / (C/12 + S/32)			
A	0.0052	0.02	0.32	0.013	0.017	0.032	0.078	0.0067	-	1.2	892	4.4×10 ⁴	*2
B	0.0031	0.02	0.46	0.035	0.014	0.033	0.048	0.0027	-	1.2	877	3.1×10 ⁴	*2
C	0.0033	0.01	0.63	0.015	0.022	0.033	0.070	0.0028	-	1.3	865	7.7×10 ⁴	*2
D	0.0032	0.01	0.94	0.016	0.018	0.034	0.076	0.0036	-	1.6	857	8.7×10 ⁴	*2
E	0.0129	0.02	0.37	0.016	0.008	0.032	0.115	0.0059	-	1.5	883	7.8×10 ³	*3
F	0.0017	0.44	0.44	0.091	0.007	0.031	0.085	0.0041	-	4.1	874	6.5×10 ³	*3
G	0.0044	0.02	0.17	0.016	0.009	0.028	0.076	0.0045	-	2.0	905	4.1×10 ³	*3
H	0.0035	0.01	1.15	0.014	0.006	0.031	0.066	0.0037	-	2.3	825	4.6×10 ³	*3
I	0.0032	0.01	0.44	0.088	0.008	0.036	0.074	0.0108	-	1.5	881	8.2×10 ³	*3
J	0.0028	0.02	0.46	0.013	0.005	0.036	0.039	0.0034	-	1.4	868	6.9×10 ³	*3
K	0.0045	0.01	0.44	0.018	0.031	0.029	0.106	0.0045	-	1.4	876	6.3×10 ⁵	*3
L	0.0039	0.01	0.55	0.013	0.043	0.032	0.125	0.0036	-	1.4	872	9.8×10 ⁵	*3
M	0.0050	0.01	0.46	0.014	0.017	0.033	0.050	0.0058	-	0.7	881	4.3×10 ³	*3
N	0.0007	0.01	0.45	0.021	0.022	0.035	0.077	0.0032	-	1.8	879	5.2×10 ³	*3
O	0.0038	0.01	0.36	0.011	0.019	0.037	0.081	0.0031	0.005	1.6	891	2.9×10 ⁴	*2

*1: Quantity of precipitates with size of 1000 to 10000Å.
Steel types F and I have precipitates of FeTiP alloy
and the other steel types are Ti₄C₂S₂ type alloy.

*2: Example of the present invention

*3: Comparison example

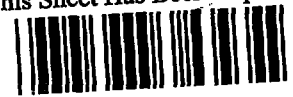


Table 6

Steel type	Tensile properties				Punching character- istics	Stretch- flange- ability	Remarks
	YS (N/mm ²)	TS (N/mm ²)	E1 (%)	r value	Burr height (μm)	Hole expansion limit (%)	
A	165	316	52	2.12	23	203	*1
B	158	327	51	2.03	17	216	*1
C	157	331	51	1.97	20	198	*1
D	188	382	45	1.95	17	206	*1
E	186	344	43	1.62	32	175	*2
F	221	430	33	1.74	28	151	*2
G	158	318	47	1.80	45	197	*2
H	222	359	43	1.66	39	189	*2
I	224	356	42	1.72	33	174	*2
J	155	321	47	1.84	42	205	*2
K	164	327	44	1.85	36	162	*2
L	168	322	42	1.77	35	133	*2
M	193	213	43	1.43	39	158	*2
N	143	298	50	1.99	51	194	*2
O	183	322	49	1.94	16	203	*1

*1: Example of the present invention

*2: Comparison example

Results from Tables 5 and 6 can be interpreted as follows.

In the embodiment, steel types A, B and C are soft steel while steel type D is high strength steel that satisfy the stipulated conditions for this invention.



Steel type O is an embodiment including boron as an element. All of these types, along with having superior tensile properties also provide superior performance for punching and machining.

In contrast, steel types E through J all had poor punch processability due to insufficient sulfur content. In addition, the steel type E had too high a carbon content so tensile properties are poor because TiC is produced. The steel type H had too high a manganese content so that tensile properties and stretch-flangeability is poor because MnS is produced. The steel type M had an insufficient amount of carbon so that tensile properties are poor and further had poor punch processability and stretch-flangeability because an inadequate amount of $Ti_4C_2S_2$ precipitates are produced. The following is not shown in Table 2 however, because the silicon content in steel type F is too large, a silicon oxide layer formed during the electrical galvanizing caused variations in the galvanized layer and the sealing of the galvanized layer was poor. In steel type K it was verified that, because the sulfur content was too large, the tensile properties were bad even though the punch processability was satisfactory, furthermore surface defects such as blisters and slivers were verified on the steel sheet surface after rolling. In steel types F and M, the balance between the amount of Ti and the amount of carbon and steel was poor so that the conditions in the above mentioned formula (1) could not be satisfied and consequently besides the tensile

properties balance being bad, the punch processability and stretch-flangeability was poor and the resistance to aging unsatisfactory.

Fourth Embodiment

The steel type B (877°C at Ar₃ point) shown in Table 5 was utilized. The hot rolling was performed in the same way as for the third embodiment except for the heating temperature, hot rolling finishing temperature and coiling temperature which were changed as shown in Table 7. The hot rolled steel sheet was manufactured to a width of 3.2 mm and further cold rolled to a thickness of 0.8 mm. After performing consecutive annealing for 1 minute at 800°C, 1 percent temper rolling was carried out to obtain the cold rolled steel. The respective tensile properties, stretch-flangeability and punch processability were investigated and the results obtained are shown in Table 8.



Table 7

Steel type	Hot rolling condition (°C)			Precipitates figure and status (piece/mm ²)	Remarks
	Heating temp.	Finishing temp.	Coiling temp.		
B1	1230	935	610	6.4×10^5 TiS type	*1
B2	1180	920	630	3.1×10^4 Ti ₄ C ₂ S ₂ type	*2
B3	1145	915	620	6.3×10^4 Ti ₄ C ₂ S ₂ type	*2
B4	1070	930	605	8.7×10^3 MnS type	*1
B5	1175	995	630	5.5×10^5 MnS type	*1
B6	1170	895	630	5.2×10^4 Ti ₄ C ₂ S ₂ type	*2
B7	1180	850	625	5.1×10^3 FeTiP type	*1
B8	1190	915	735	3.8×10^3 FeTiP type	*1
B9	1180	925	680	3.6×10^4 Ti ₄ C ₂ S ₂ type	*2
B10	1175	930	580	8.8×10^3 Ti ₄ C ₂ S ₂ type	*1

*1: Comparison example

*2: Example of the present invention

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Table 8

Steel type	Tensile properties				Punching character- istics	Stretch- flange- ability	Remarks
	YS (N/mm ²)	TS (N/mm ²)	El (%)	r value	Burr height (μm)	Hole expansion limit (%)	
B1	164	326	49	1.81	32	179	*1
B2	156	327	51	2.03	13	216	*2
B3	155	322	50	2.11	19	196	*2
B4	161	323	47	1.88	36	181	*1
B5	157	321	45	1.79	34	186	*1
B6	156	319	52	2.06	18	223	*2
B7	152	315	42	1.65	26	177	*1
B8	160	328	45	1.61	30	175	*1
B9	150	323	50	1.94	21	194	*2
B10	178	335	42	1.60	30	173	*1

*1: Comparison example

*2: Example of the present invention

The symbols B1 through B4 in Tables 7 and 8 show the suitable temperature ranges for the finishing temperature and coiling temperature. In particular, when investigating the effect of the heating temperature, it was found in steel types where heating was performed in a range from 1,100 to 1,200°C (symbols B2, B3) the Ti₄C₂S₂ based precipitates was produced in suitable sizes and amounts and the tensile properties, stretch-flangeability and punch processability were superior in each case. In contrast, when the heating temperature in the comparison sample



(symbol B₁) exceeded 1,200°C, precipitates mainly of MnS were formed, and when the temperature dropped below 1,100°C in the comparison sample (symbol B₄) precipitates mainly of TiS were formed with the punch processability being poor in both cases.

The symbols B₅ through B₇ show the suitable temperature ranges for the heating temperature and coiling temperature. In particular, when investigating the effect of the finishing temperature, it was found that in steel types where heating was performed in a range from 1,100 to 1,200°C (symbols B₆) the Ti₄C₂S₂ based precipitates was produced in suitable sizes and amounts and the tensile properties, stretch-flangeability and punch processability were superior in each case. In contrast, when the finishing temperature in the comparison sample (symbol B₅) was too high, precipitates only of MnS were formed, and when the heat roll finishing temperature was too low in the comparison sample (symbol B₇) precipitates mainly of FeTiP were formed with the punch processability being inadequate in both cases.

The symbols B₈ through B₁₀ show the suitable temperature ranges for the heating temperature and the heat roll finishing temperatures. In particular, when investigating the effect of the coiling temperature, it was found that in steel types where the coiling temperature was in the correct range (symbols B₉) the Ti₄C₂S₂ and the TiS based precipitates was produced in suitable sizes and amounts and the tensile properties, stretch-flangeabilities



and punch processability were superior in each case. In contrast, when the coiling temperature in the comparison sample (symbol B₈) was too high, precipitates mainly of FeTiP was formed and satisfactory stretch-flangeability could not be obtained. When the coiling temperature in the comparison sample (symbol B₁₀) was too low, the Ti₄C₂S₂ and the TiS based precipitates were not produced in sufficient amounts and the punch processability and stretch-flangeability performance was somewhat low.

Fifth Embodiment

Cold rolled steel sheets obtained utilizing steel types A, B and C from among the cold rolled steel sheet of the third embodiment were galvanized on the surface in accordance with the usual methods to form a galvanized layer of 1 to 50 g/m². Chromate treatment was then performed so that the chromium precipitate formed over the galvanized layer is converted to metallic chromium at 10 mg/m².

A resin base of ethylene, ester or urethane resin was used for mixing with colloidal silicon particles converted to solid type, of 4 to 6 μ m in size and in a 10% portion mix in the resin material applied at 0.05 to 3 g/m² in order to obtain the surface treated steel sheet. The resistance to corrosion, resistance to fingerprint and grounding were evaluated and the results are shown in Table 9.

Corrosion Resistance:

A salt spray test was performed according to the methods listed in JIS Z 2371 and the time for generation of 1% white rust evaluated.

O = 240 hours or more X = less than 240 hours

Resistance to Fingerprints:

The test piece was soaked in a 50% white-colored vaseline solution at 40°C and then extracted.

Discoloration on the vaseline coated portion and the non-coated portions was measured and evaluated. The color difference (ΔE) between the vaseline coated and non-coated portions was "3 or less" thus showing good resistance to fingerprints.

O = ΔE of 3 or less X = more than ΔE

Grounding:

The conductivity of the surface of the test piece was measured in surface resistance across tester terminals spaced 100 mm apart and the results evaluated.

O = surface resistance of 200 ohms or less X = surface resistance of 200 ohms or more

Overall Evaluation:

O = Satisfactory X = Unsatisfactory



Table 9

No.	Steel type	Zn adhering amount (g/m ²)	Resin type *)	Resin adhering amount (g/m ²)	Corrosion resistance	Finger-print resistance	Grounding	Overall evaluation	Remarks
1	A	15	Ethylene	0.5	o	o	o	o	Embodiment
2	A	10	Ethylene	0.5	o	o	o	o	
3	B	20	Ethylene	0.1	o	o	o	o	
4	B	40	Urethane	0.3	o	o	o	o	
5	C	30	Ester	2.5	o	o	o	o	
6	B	2	Ethylene	0.05	x	x	o	x	Comparison example
7	B	20	Urethane	3.0	o	o	x	x	
8	B	20	None	—	x	x	o	x	
9	C	20	Polyester	0.05	x	x	o	x	

*) : Details on resin type

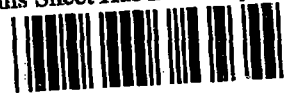
Ethylene: Ethylene polymer resin containing 20% acrylic acid by weight consisting of ethylene non-saturated carboxylic acid

Ester: Polyester resin, product brand name of "BYRON 20SS" made by Toyo Boseki Co.

Urethane: Polyurethane resin, product brand name of "SUPERFLEX" made by Daiichi Kogyo Chemical Co.

Results from Table 7 can be interpreted as follows.

The chemical compositions, and the amounts of the electrically galvanized layer and plastic coating steel material of embodiments No. 1 through 5 satisfied the specified conditions of this invention. An extremely



superior effect was also obtained for the corrosion resistance, resistance to fingerprints, and grounding.

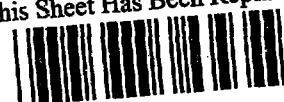
In contrast, No. 6 had poor corrosion resistance and poor resistance to fingerprints due to insufficient adherence amounts of the electrically galvanized layer and the plastic coating. No. 7 had poor grounding because the plastic coating was too large. No 8 had poor corrosion resistance and poor resistance to fingerprints because the plastic layer had not been applied. No. 9 was unable to provide satisfactory corrosion resistance and resistance to fingerprints because the amount of plastic coating was insufficient.

Effect of the Invention:

This invention is comprised as described above and along with the composition elements of the steel material, the content in particular of the titanium, sulfur, manganese and nitrogen are regulated and the interrelation of the sulfur, nitrogen and carbon amounts with the titanium amount suitably controlled to produce $Ti_4C_2S_2$ precipitates in the proper amounts and size. This allows thin steel plate with extremely excellent punch processability to be provided without loss to the forming or the mechanical properties of the metal. The method of this invention also allows thin steel plate with these features to be reliably manufactured at the industrial level.



This Sheet Has Been Replaced



WHAT IS CLAIMED IS :

1. A steel sheet providing superior mechanical properties, including precipitates constituting mainly $Ti_4C_2S_2$ and satisfying the following conditions for specific amounts of elements by mass % such that :

Carbon : 0.0010 to 0.010%

Silicon : 1.0% or less

Manganese : 0.1 to 1.0%

Phosphor : 0.1% or less

Sulfur : 0.01 to 0.025%

Nitrogen : 0.01% or less

Titanium : 0.2% or less

Remainder : Fe and unavoidable impurities,

said elements satisfying the conditions of the following formulas:

$$(Ti^*/48)/(C/12 + S/32) = 0.8 \text{ to } 4.0$$

$$Ti^* = Ti - (48/14)N$$

2. A steel sheet of superior mechanical properties according to claim 1, wherein precipitates are comprised internally mainly of $Ti_4C_2S_2$, with a size of 1,000 to 10,000Å and has a count of 5×10^3 pcs/mm² or more.



3. A steel sheet of superior mechanical properties according to claim 2, wherein the steel sheet is a hot rolled steel sheet and satisfies the following formula.

$$(Ti^*/48)/(C/12 + S/32) = 1.0 \text{ to } 3.0$$

$$Ti^* = Ti - (48/14)N$$

4. A steel sheet of superior mechanical properties according to claim 2, wherein the steel sheet is a cold rolled steel sheet and precipitates mainly comprising $Ti_4C_2S_2$, also include TiS with $Ti_4C_2S_2$ and size of said precipitates is 1,000 to 10,000Å and said precipitates have a count of 1×10^4 to 5×10^5 pcs/mm².

5. A steel sheet of superior mechanical properties according to any of claims 1 through 4, wherein the steel sheet satisfies the following conditions for specific amounts of elements by mass % such that :

Carbon : 0.0010 to 0.008%

Silicon : 0.25% or less

Manganese : 0.20 to 1.0%

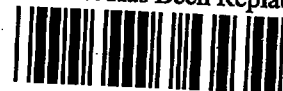
Phosphor : 0.05% or less

Titanium : 0.15% or less

6. A galvanized steel sheet according to claim 1 wherein at least one side of the steel sheet is galvanized with zinc or zinc alloy in amounts of 3 to 40 g/m².



This Sheet Has Been Replaced



7. A resin coating steel sheet according to claim 5, wherein a plastic coating is formed over said zinc or zinc alloy galvanized sheet to adhere in amounts of 0.1 to 2.5 g/m².

8. A manufacturing method for hot rolled steel sheet providing superior mechanical properties and satisfying the following conditions for specific amounts of elements by mass % such that:

Carbon : 0.0010 to 0.010%

Silicon : 1.0% or less

Manganese : 0.1 to 1.0%

Phosphor : 0.1% or less

Sulfur : 0.01 to 0.025%

Nitrogen : 0.01% or less

Titanium : 0.2% or less,

Remainder : Fe and unavoidable impurities,

said elements satisfying the conditions of the following formulas:

$$(Ti^*/48)/(C/12 + S/32) = 1.0 \text{ to } 3.0$$

$$Ti^* = Ti - (48/14)N$$

said manufacturing method comprising the steps of:



heating said steel within a temperature range of 1,100 to 1,200°C, and completing hot rolling within the temperature range (Ar₃ transformation temp. +80°C) to (Ar₃ transformation temp. -40°C) followed by coiling at a temperature range not more than 700°C to produce precipitates comprised internally mainly of Ti₄C₂S₂, with a size of 1,000 to 10,000Å and a count of 5×10^3 pcs/mm² or more.

9. A manufacturing method for cold rolled steel sheet providing superior mechanical properties and satisfying the following conditions for specific amounts of elements by mass % such that :

Carbon : 0.0010 to 0.010%

Silicon : 1.0% or less

Manganese : 0.1 to 1.0%

Phosphor : 0.1% or less

Sulfur : 0.01 to 0.025%

Nitrogen : 0.01% or less

Titanium : 0.2% or less,

Remainder : Fe and unavoidable impurities,

said steel satisfying the conditions of the following formulas:

$$(Ti^*/48)/(C/12 + S/32) = 0.8 \text{ to } 4.0$$

$$Ti^* = Ti - (48/14)N$$



said manufacturing method comprising the steps of:
heating said steel within a temperature range of 1,100 to 1,200°C, and completing hot-rolling within the temperature range (Ar₃ transformation temp. +80°C) to (Ar₃ transformation temp. -40°C) followed by coiling at a temperature range between 600 to 700°C, and after cold rolling of the steel, carrying out annealing to produce precipitates comprised internally mainly of Ti₄C₂S₂ or Ti₄C₂S₂ and TiS, with a size of 1,000 to 10,000Å and a count of 1×10^4 to 5×10^5 pcs/mm².

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FIG. 1

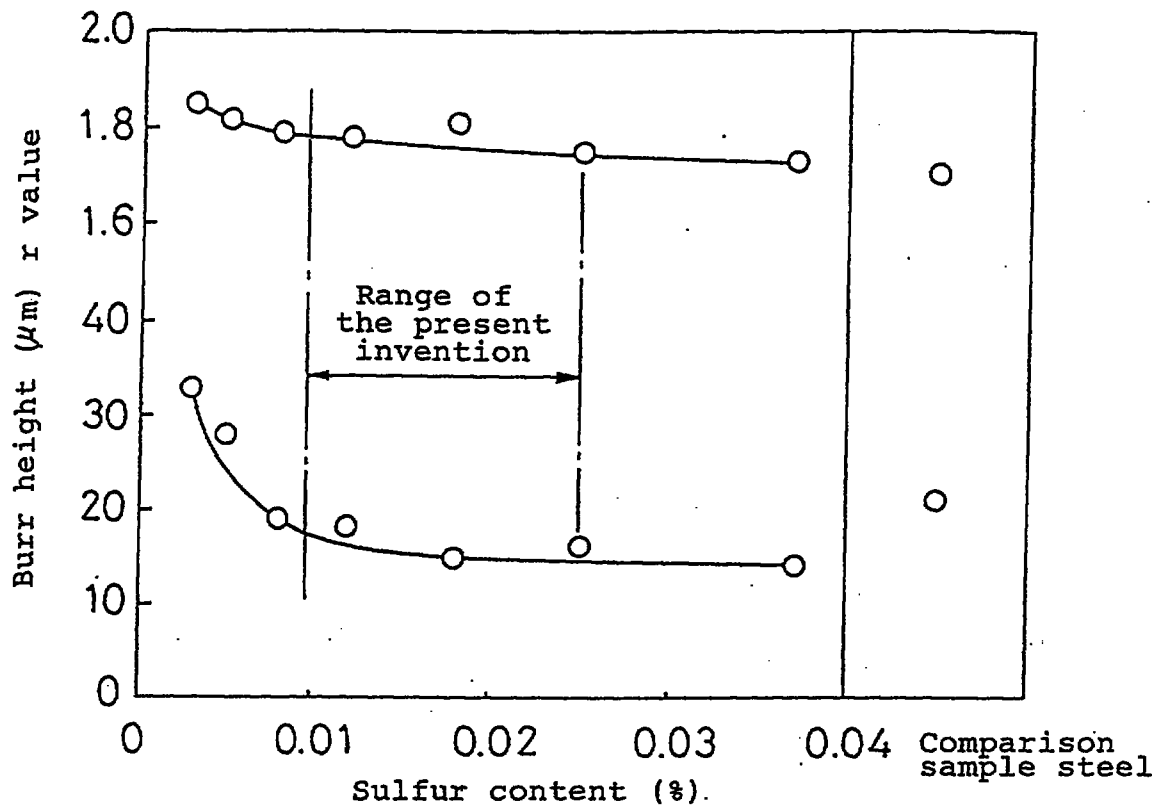
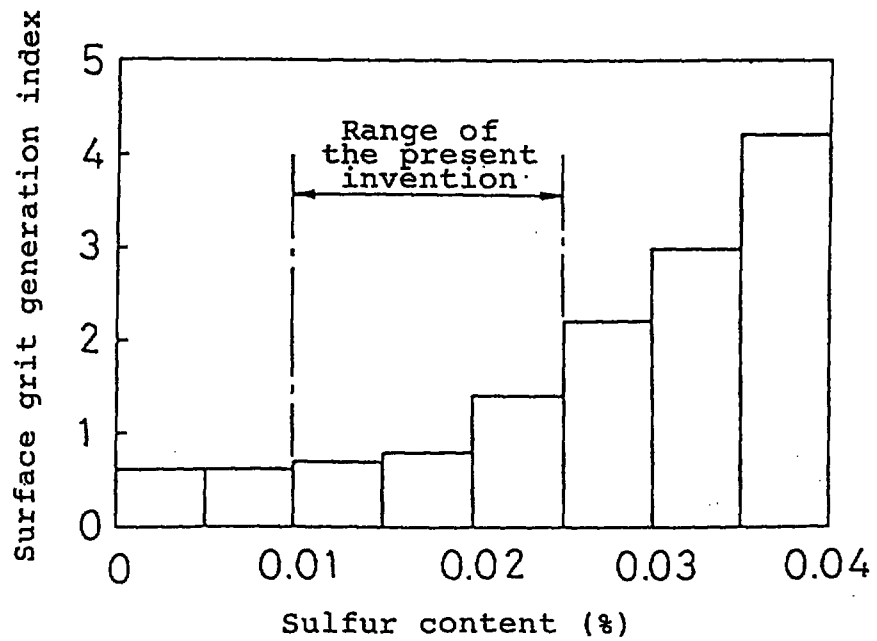


FIG. 2



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A B S T R A C T

A steel sheet is disclosed, said steel sheet being made of a steel containing specific amounts of carbon, silicon, manganese, phosphorus, sulfur, nitrogen, and titanium, with said steel also satisfying the conditions of the following formulas:

$$(Ti^*/48)/(C/12 + S/32) = 0.8 \text{ to } 4.0$$

$$Ti^* = Ti - (48/14)N$$

of which, a steel sheet and manufacturing method thereof providing said steel sheet having excellent mechanical properties, forming and punch processability characteristics and internally including precipitates constituting mainly $Ti_4C_2S_2$, or $Ti_4C_2S_2$ and TiS . Said steel sheet further, formed with a zinc or galvanized surface and that surface is coated with anti-corrosive, fingerprint-resistant plastic covering.

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TITLE OF THE INVENTION

STEEL SHEET HAVING EXCELLENT PROCESSING CHARACTERISTICS,
MANUFACTURING METHOD THEREFOR, AND GALVANIZED STEEL SHEET
AND A RESIN COATING STEEL SHEET

BACKGROUND OF THE INVENTIONField of the Invention

Hot rolled steel sheets and cold rolled steel sheets are used in a wide variety of applications as outer panels for automobiles and household electrical appliances with various characteristics required for each different application. For example the metal sheet used in computers and household appliances such as VTR (video tape recorders) and tape recorder chassis often require punching processing of movable chassis parts. The edges of these parts ideally should not have any burrs projecting out any more than a specified height from the part surface. For example many times a hole is punched out, for the pin forming the shaft of the VTR head, however when burrs are present this pin cannot be inserted during the assembly process. Also, troubles may occur such when a sliding part binds or does not function well when positioned at the punched surface, or when the "burr" collapses and causes an electrical short.

Description of the Related Art**REPLACEMENT SHEET**

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REPLACEMENT SHEETS SG

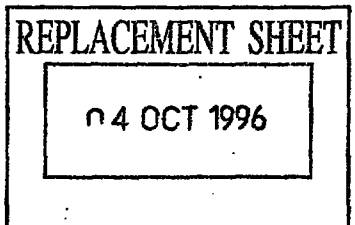
- ☒ Description : paged 1.. to paged 2..
- ☒ Claim(s) : paged 2.. to paged 3..
- ☒ Drawing(s) : paged 4.. to paged 5..
- ☒ Abstract : paged 6.. to paged 7..

DATE OF RECEIPT 4/10/96

Conventionally, low-carbon Al killed steel is usually employed in these kind of material applications such as punch processability. In this low-carbon Al killed steel, the carbon precipitates into a rough crystal particle layer of brittle cementite (iron carbide) effective in the generation of cracks during the punch process so that few burrs occur, and friction wear and shearing load can be kept small. MnS precipitates has the same effect on generation of cracks and the same results as with cementite have been confirmed.

However precipitates like cementite and MnS are dominant elements in controlling critical metal deformation ability, their secondary phase which is an origin of crack generation, causes problems during extrusion flange and stretch-flangeability processes. Therefore, even though the low-carbon Al killed steel is fine for punch processability, it is poorly suited for applications in which the edge of the punched surface must undergo secondary processing such as flange forming or stretch-flangeability.

Recently on the other hand, in order to produce ever more complicated shapes for the latest machined products and also meet user demands for more simplified press forming, the flange characteristics and stretch-flangeability processing for products must attain a yet superior level. Currently, in order to meet these demands, much use is made of IF-based steel which is super-low



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carbon steel added with carbon - nitrogen compound elements such as tin or niobium in prescribed amounts.

This IF-based steel having low yield stress, high elongation and superior press-formability has come to be widely used as a part material in processes accompanying a high degree of material deformation such as automobile body material. However conventional IF-based has drawbacks such as poor punch processability compared with low-carbon Al killed steel and large burrs on the edges after punching. The finish surface roughness and cutting chip disposal during machining are also unsatisfactory, making the IF-based steel impractical for use according to the particular application.

In other words for press forming of household appliances and automobile parts which are mainly made by being punched out from metal blanks, the above mentioned IF-based steel is unsuitable in spite of superior general forming because of poor punch processability compared to low-carbon Al killed steel and large burrs on the edges of the steel after punch processability. For instance when used in automobile parts sections of the steel with these burrs have poor adhesion after electro-precipitation processing causing bad effects like corrosion. Another problem is that when stacking boards of punched metal sheet for shipping, a metal powder is generated due to friction wear from the burrs during transport which in turn scratches the product surface. Many applications require drilling or thread cutting, however the inferior finish

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surface roughness and cutting chip disposal of the IF-based steel from machining are pointed out as drawbacks.

In order to improve the punch processability (and machinability during machining), method related later are feasible. However, in spite of the fact that only a mere portion of the metal is actually being punched, the mechanical properties of the other portions of the metal must be sacrificed, causing insufficient strength to become a serious problem.

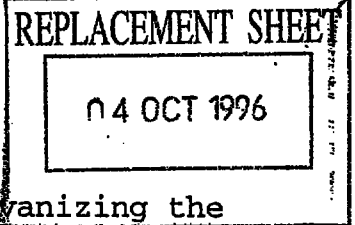
Various technical methods have been tried to improve the quality of the punched portions of the steel sheets such as correct clearances and utilizing various punch and die shapes. Methods have been proposed for the workpiece material such as hardening of the steel sheet or hardening the surface layer of the steel sheet. One specific example of a steel sheet hardening method is addition of reinforcing solid solution elements such as phosphorus. Another specific examples of hardening the surface of the steel is a method for applying plastic strain to the surface layers by rolling the steel sheet after annealing or a method for nitriding or carburizing the surface (Japanese Patent Laid-open Nos. Hei 1-255626, 2-133561, 3-199343 and 3-202442) etc. However in the former method, though the punch processability is improved, the essential mechanical properties of steel such as elongation and the r value deteriorate greatly. In the latter method of nitriding or carburizing, special equipment is required. Methods for generating large amounts of MnS precipitates

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material by adding manganese and sulfur has also been proposed (see Japanese Patent Laid-open Nos. Hei 1-230748 and 6-73457). However, these methods greatly increase the amount of sulfur in the steel, not only making the steel prone to cracks during processing under heat but also creating a new problem of frequent occurrence of point defects referred to as blow holes and blisters and surface defects referred to as slivers.

In view of the above, rather than just meeting demands for overall satisfactory forming, the steel also has to meet needs for superior cutting and punch processability demanded for steel in household appliance and automotive products. What is urgently needed is not a huge increase in additives such as sulfur but development of an improved steel with constituent elements near those of super-low carbon IF-based steel while also possessing superior forming and punch processability characteristics.

Galvanizing the steel and then applying a plastic layer on the galvanized surface is known as a basic process for preventing corrosion and improving the outer appearance or for inhibiting fingerprints during handling (improving fingerprint resistance). However steel sheet used in electrical panels or electrical equipment boxes normally must have the box electrically grounded, making electrical conductivity of the box an essential characteristic. However in order to assure this electrical conductivity the plastic layer cannot be made sufficiently thick enough to guarantee resistance to corrosion or fingerprints. To



solve this problem, method was proposed for galvanizing the steel and then using an extremely thin organic plastic layer to improve fingerprint resistance while still being thin enough to provide adequate surface conductivity for grounding of the steel. The extremely thin organic plastic layer however proved insufficient to simultaneously meet demands for both electrical grounding and fingerprint resistance. Therefore development of a surface-treated steel providing satisfactory electrical grounding and fingerprint resistance was still needed.

SUMMARY OF THE INVENTION

In consideration of the foregoing situation, it is an object of this invention to provide a steel sheet by means of good adjustment of chemical constituents, which maintains the superior forming and mechanical properties of conventional IF-based steel sheet, with no problems such as internal defects or surface defects occurring, and also offers good punch processability with no burrs occurring.

Another objective is to provide superior forming, which in this invention, are properties demonstrating superior processing not only for deep draw and protrusion forming but also for flange processing and stretch-flangeability after punching the steel.

A still further objective of the invention is to provide a galvanized steel sheet having good machinability or processing by using the steel sheet mentioned above as a base material and galvanizing the surface.

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A yet further objective of the invention is ~~to provide~~ the steel sheet with a plastic layer having good resistance to corrosion and fingerprints and no loss of grounding ability, by means of applying a plastic layer over the galvanized surface.

An additional object of the invention is to provide a reliable method for manufacture of a steel having the above characteristics, that is both stable and suitable for production on an industrial scale.

In order to obtain the above objects, the steel of this invention must satisfy conditions for:

Carbon of 0.0010 to 0.010% by weight and more preferably 0.0010 to 0.008% by weight;

Silicon of 1% or less by weight and more preferably 0.25% or less by weight;

Manganese of less than .1 to 1% by weight and more preferably 0.2 to 1% by weight;

Phosphorus of less than 0.1% by weight and more preferably less than 0.05%;

Sulfur of 0.01 to 0.025% by weight;

Nitrogen of less than 0.01% by weight;

Tin of less than 0.2% by weight and more preferably less than 0.15% and further satisfying:

$$(Ti^*/48)/(C/12 + S/32) = 0.8 \text{ to } 4.0$$

However,

$$Ti^* = Ti - (48/14)N$$

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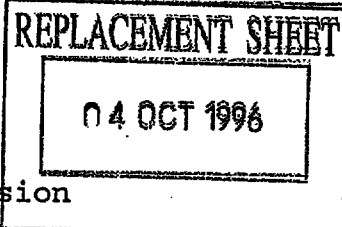
with further conditions of internally including mainly $\text{Ti}_4\text{C}_2\text{S}_2$ and the remainder comprising iron and unavoidable impurities.

The precipitates composed mainly of $\text{Ti}_4\text{C}_2\text{S}_2$ preferably has a size of 1,000 to 10,000Å and a precipitation count of 5×10^3 pcs/mm² (preferably less than 5×10^5).

The steel of this invention is cold rolled or hot rolled and when hot rolled, the value calculated from said $(\text{Ti}^*/48)/(\text{C}/12 + \text{S}/32)$ is in the range of 1.0 to 3.0 and the size of the precipitates mainly of $\text{Ti}_4\text{C}_2\text{S}_2$ is 1,000 to 10,000Å and preferably said precipitates have a count of 5×10^3 pcs/mm².

When cold rolled, the value calculated from said $(\text{Ti}^*/48)/(\text{C}/12 + \text{S}/32)$ is in the range of 0.8 to 4.0 and more preferably in the range 1.0 to 2.5. The size of the precipitates mainly of $\text{Ti}_4\text{C}_2\text{S}_2$ also contains TiS in addition to the $\text{Ti}_4\text{C}_2\text{S}_2$, and the size of the precipitates is 1,000 to 10,000Å with preferably a count of 5×10^5 pcs/mm².

While said hot rolled steel or cold rolled steel can now be utilized as it is, the surface can be galvanized to improve the corrosion resistance and outer appearance. In this invention, this process includes formation of 3 to 4 g/m² of zinc galvanized layer on at least one side of the hot rolled steel or the cold rolled steel sheet, and then further forming a plastic coating of 1 to 2.5 g/m² on the zinc galvanized layer of the steel. This plastic coating



of the steel serves to further improve the corrosion resistance and the resistance to fingerprints.

This invention is also characterized by manufacturing methods for the cold rolled steel and hot rolled steel sheets. In the preferred makeup of the hot rolled steel manufacturing method, composition of the said elements for the hot rolled steel sheet conditions are satisfied and further, the value calculated from said $(Ti^*/48)/(C/12 + S/32)$ is within a range of 1.0 to 3.0, and after the steel has been heated within a temperature range of 1,100 to 1,200°C, heat form rolling is completed within the temperature range (Ar₃ transformation temp. +80°C) to (Ar₃ transformation temp. -40°C) next, coiling at a temperature range below 700°C produces precipitates comprised internally mainly of Ti₄C₂S₂, with a size of 1,000 to 10,000Å and a count of 5×10^3 pcs/mm².

The preferred version of the cold rolled steel manufacturing method is characterized by, a chemical composition satisfying said elements listed previously and further, the value calculated from said $(Ti^*/48)/(C/12 + S/32)$ is within a range of 0.8 to 4.0. After the steel has been heated within a temperature range of 1,100 to 1,200°C, heat form rolling is completed within the temperature range (Ar₃ transformation temp. +80°C) to (Ar₃ transformation temp. -40°C). Coiling at a temperature range between 600 to 700°C is then performed, and after cold rolling of the steel, annealing is carried out to produce a precipitates

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comprised internally mainly of $Ti_4C_2S_2$, with a size of 1,000 to 10,000Å and a count of 1×10^4 to 5×10^5 pcs/mm².

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph showing the effect of sulfur content in the steel on burr height and the r value during punch processability.

Fig. 2 is a graph showing the relation of sulfur content in the steel to surface flaw generation index.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

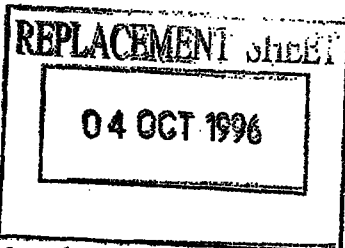
As described above, the steel (hereafter including both cold rolled steel and hot rolled steel) of this invention, along with having specific constituents in the steel, internally comprises precipitates mainly of $Ti_4C_2S_2$, or $Ti_4C_2S_2$ and TiS , with said precipitates preferably having a specified size and amount. These conditions which are basically similar to the composition of the conventional super low carbon IF steel allow superior press characteristics to be maintained and succeed in attaining a substantial improvement in punch and machining characteristics.

More specifically, by keeping the sulfur content to a minimum to improve punch processability, the sulfur is formed into precipitates mainly of $Ti_4C_2S_2$, or $Ti_4C_2S_2$ and TiS , by preferably regulating the size and amount of this precipitates the defects pointed out in the examples of the conventional art are avoided and a steel with superior

forming and punching processing and also with satisfactory flange processing and stretch-flangeability in later processes can be obtained. In order to guarantee this superior punch processability, the burr height after punch processability should be less than 25 μm and more preferably less than 15 μm .

Normally, press and punch processability is performed at room temperatures and the material temperature is not raised substantially, because obtaining said improved results in terms of condition, size and dispersion of the precipitates and inclusions requires processing at room temperature. Also, during machining the temperature is quite high so that the inclusion in the material must be of a type able to provide the desired material machining characteristics by fusing (of the inclusion) in the temperature range occurring during machining. The precipitates composed mainly of $\text{Ti}_4\text{C}_2\text{S}_2$ is provided with all of these characteristics and a large improvement in machining such as punch processability has been verified. The TiS precipitates are large compared to the $\text{Ti}_4\text{C}_2\text{S}_2$ material and can cause surface defects but when the size is within a range of 1,000 to 10,000 $\text{\AA}$, such surface defects do not occur and the improved machining and punch processability characteristics were confirmed to be the same as those for the $\text{Ti}_4\text{C}_2\text{S}_2$ material.

When observing the punched steel sheet on the microscopic level however, it seems that a sheared surface is first formed on the front and back of the steel sheet



accompanying the contact of the falling punch with the steel sheet. The concentrated stress on said sheared surface causes strong shear deformation resulting in formation of voids which in turn form cracks which grow larger on the front and back of the sheet and when these cracks join together the punched steel is obtained. Therefore promoting development of the above mentioned voids and cracks should prove effective in reducing the size of burrs after punch processability. In the $Ti_4C_2S_2$ and TiS however, the precipitates is relatively large so that development of cracks and voids can progress in the vicinity of the strong shear deformation. Consequently punch processability is remarkably improved and the size of burrs is also reduced.

In stretch-flangeability on the other hand, the edges of the hole formed by punching are widened in so-called "flange up" processing by means of conic or cylindrical punches. The voids formed at the boundaries join and become cracks, piercing through the sheet. Therefore it is preferable to reduce the amount of precipitates and inclusions which promotes forming of these voids and cracks.

As can be seen, different effects are exerted on the punching and burring characteristics by the size of the precipitates and inclusions. Research by the inventors as related below, confirms that among the various precipitates and inclusions, if the size and dispersion amounts in particular of the $Ti_4C_2S_2$ or the $Ti_4C_2S_2$ and TiS are

controlled in optimal amounts, the dual goals of punch processability and stretch-flangeability can be achieved without surface defects.

Also the precipitates and inclusions in the super-low carbon IF steel, other than MnS and Al_2O_3 which are normally included in steel, also comprise titanium additives such as TiC , $\text{Ti}_4\text{C}_2\text{S}_2$, TiS , TiN , FeTiP , Ti_2O ; and $\text{Nb}(\text{C},\text{N})$ in steel with niobium additives. These have their own special characteristics relative to respective sizes and distributions and the following pertinent information has been verified after observing the effects on the formability, machinability, punching and burring characteristics of the steel.

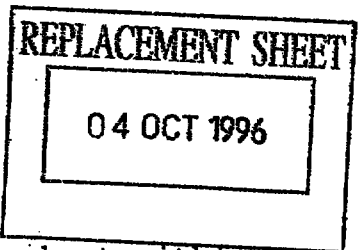
$\text{Ti}_4\text{C}_2\text{S}_2$, TiS :

If the size of $\text{Ti}_4\text{C}_2\text{S}_2$ precipitates is 1,000 to 10,000Å, and the quantity for hot rolled steel is 5×10^3 pcs/mm² or more, and for cold rolled steel is within 1×10^4 to 5×10^5 pcs/mm², then not only will the machinability and punch processability be remarkably improved but there will be virtually no adverse effects on formability for burrs etc. The above difference in allowable quantity between hot and cold rolled steel is due to the high surface precision required of cold rolled steel. This limit was established for the cold rolled steel due to the possibility of excessive amounts of said precipitates adversely affecting the surface precision. A slab of steel satisfying conditions later related for the

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constituents of the precipitates mainly comprising $Ti_4C_2S_2$ was heated within a temperature range of 1,100 to 1,200°C and then heat form rolling completed within the temperature range (Ar₃ transformation temp. +80°C) to (Ar₃ transformation temp. -40°C). For hot rolled steel the material was next wound up at a temperature range below 700°C. For cold rolled steel however, the coiling was performed within a range set at 600 to 700°C after heat rolling and after next performing cold rolling by the usual method, annealing was carried out in an efficient process. During heating of the above slab, TiS may precipitate during final stages of $Ti_4C_2S_2$ generation. The size of the TiS material at completion of heat rolling is considerably large compared to that of the $Ti_4C_2S_2$ material so that surface defects may possibly occur when used in heat rolling. Therefore when actually using the steel, conditions must be set to limit the TiS precipitates as much as possible.

However in the cold rolling performed after the hot rolling, this large TiS precipitates break up into fine pieces in the cold rolling process and almost no growth of the TiS precipitates occur in the later annealing process so improved punch processability is maintained and adverse effects leading to surface defects are eliminated so that virtually the same effects as the $Ti_4C_2S_2$ material are displayed. Therefore when using as cold rolled steel which includes TiS in the precipitates mainly of $Ti_4C_2S_2$, a remarkable improvement in the punch processability can be

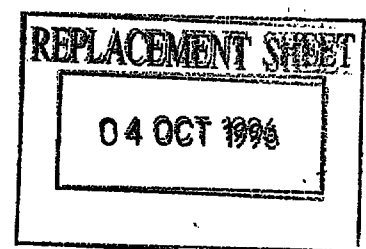


achieved if the size of the precipitates is kept within 1,000 to 10,000Å and the amount is kept within 1×10^4 to 5×10^5 pcs/mm².

Further, deviations from the preferred conditions for heating temperatures and hot rolling will reduce the quantity of precipitates comprising mainly $Ti_4C_2S_2$ or $Ti_4C_2S_2$ and TiS so that not only is a poor improvement shown for punch processability and stretch-flangeability but TiC is produced which causes adverse effects on steel forming and the object of this invention cannot be achieved.

TiC, Nb (C,N):

When the precipitates are approximately 100Å, the size is too small so that not only is an adverse effect wrought on the steel forming, but the improvement in punch processability is poor. A process is known (Japanese Patent Laid-open No. Hei 6-73457) for improving the punch processability and forming in super-low carbon IF steel by adding a compound of titanium and nobium to the cold rolled steel. However, evaluation by the inventors confirmed that addition of nobium within a range of 0.003 to 0.03% in the steel generated $Nb(C,N)$ in the steel and consumed the carbon with the result that the $Ti_4C_2S_2$ effective in improving the punch processability and stretch-flangeability was not produced and the object of the invention could not be achieved.



FeTiP:

As precipitates FeTiP have a size approximating that of $Ti_4C_2S_2$ and is effective in improving punch processability and stretch-flangeability however a film precipitate occurs on the crystal boundaries so that steel forming becomes drastically worse.

TiN:

As precipitates TiN have a size approximating that of $Ti_4C_2S_2$ and achieves equivalent improved results however it is too soft in actual use and shows almost no improvement in punch processability and poor improvement in stretch-flangeability effects. Furthermore, the machining is unsatisfactory since a rise in temperature during machining degrades the cutting effect. The nitrogen content is also difficult to regulate, so that effective improvements in machining, punching and stretch-flangeability of steel with these Ti compounds is difficult to achieve.

Ti₂O:

The size of the precipitates is on a larger scale than $Ti_4C_2S_2$, with poor improvement in punch processability and stretch-flangeability. Furthermore Ti_2O is not desirable because of possible surface defects.

MnS:

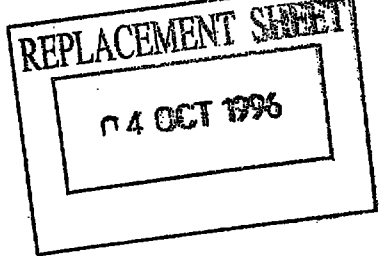
MnS has inclusions and precipitates with the former being in micron units and the latter being 1/10th of that

size. When the sulfur increases the increased inclusion mass means that punch processability is improved but as shown in the previously mentioned Japanese Patent Laid-open No. Hei 6-73457 an improved punch processability requires 0.02% or more of sulfur. A large quantity of sulfur can cause poor forming and surface defects.

As shown above there are many possible combination of compounds for obtaining and producing inclusions and precipitates in the IF-based steel sheet containing super-low carbon titanium. Among these various compounds, $Ti_4C_2S_2$ having a precipitate size of 1,000 to 10,000Å or ($Ti_4C_2S_2$ and TiS) brings out favorable effects on punching and stretch-flangeability without causing adverse effects on forming. Furthermore if the steel sheet constituents and machining conditions are suitably adjusted so that; the precipitates mainly composed of the $Ti_4C_2S_2$ or ($Ti_4C_2S_2$ and TiS) in amounts of 5×10^3 pcs/mm² or more for hot rolled steel sheet, and on the other hand, kept within a range of 1×10^4 to 5×10^5 pcs/mm² for cold rolled steel then the features can be demonstrated in an extremely effective manner. This new knowledge became the basis for the present invention. Next, the reason for setting the chemical constituents of the steel sheet of this invention are clarified.

C : 0.0010 to 0.010%

Carbon combines with titanium to produce $Ti_4C_2S_2$ and is an indispensable element. The carbon content must be at



least 0.0010%, however if the carbon content is too large, the amount of TiC produced increases and along with a decrease in the ductility or elongation of the metal, the yield stress rises and the forming and stretch-flangeability are adversely affected. In view of these facts an upper limit of 0.010% was set to ensure good forming.

Si : 1.0% or less

Silicon is an effective element for improving strength without loss of ductility or elongation but when the silicon content is too high, the oxidized layer produced during annealing grows large and exerts adverse effects on later forming processes also causing uneven distribution of the galvanized layer. Due to these reasons the silicon content is limited to 1.00% or less. Further, non-galvanized portion are prone to occur during alloy fusion galvanizing of the steel sheet due to the forming of said oxidized layer so the silicon content should preferably be restricted to 0.20%.

Mn: 0.1 to 1.0%

Manganese produces MnS and is an auxiliary element for improved stretch-flangeability and punch processability. The manganese content must be 0.10% or more to effectively demonstrate these improvements. However when the content is too large an adverse effect is wrought on the forming

and stretch-flangeability so manganese content must be limited to 1% or less.

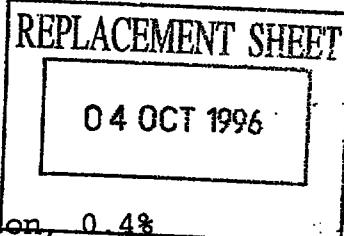
P: 0.1% or less

Phosphorus is suspended in the steel or forms FeTiP precipitates. In the former case phosphorus is a strengthening element and conversely exerts adverse effects on the forming. In the latter case on becoming precipitates, the punching and stretch-flangeability were found to be somewhat improved but the effect on forming was extremely bad so that phosphorus should be limited to 0.1% or less and preferably to 0.05% or less.

S: 0.01 to 0.025%

Sulfur combines with the later related Ti and is an indispensable element in forming precipitates comprising mainly $\text{Ti}_4\text{C}_2\text{S}_2$ or ($\text{Ti}_4\text{C}_2\text{S}_2$ and TiS). In order for these precipitates to show improved punch processability, the $\text{Ti}_4\text{C}_2\text{S}_2$ or ($\text{Ti}_4\text{C}_2\text{S}_2$ and TiS) must be in amounts of 5×10^3 pcs/mm² or more. The sulfur content must therefore be 0.010% or more. However these effects are maximized at 0.025% and when the content is excessive, not only are adverse effects exerted on the press forming but surface defects are prone to increase so the upper limit is set at 0.025%.

Incidentally, Figure 1 is a graph showing the punch processability and r value when the sulfur content is made to change from 0.002% to 0.037%, for steel sheet with a



basic composition of 0.0052% carbon, 0.01% silicon, 0.4% manganese, 0.014% phosphor, 0.03% aluminum, 0.08% titanium and 0.006% nitrogen. In the figure, box annealed type A1 killed steel (C: 0.044%, Al: 0.045%) having superior punching and mechanical characteristics is used as the comparison sample. Fig. 2 shows the sulfur content versus the percentage of surface defects.

The physical properties test was performed as follows. A vacuum dissolved, forged 40 kg metal ingot was heated to 1200°C and the rough rolled at 30 mm^t. Next, after heating this slab to 1200°C, it was hot rolled under conditions of plate thickness of 4 mm^t, finish temperature of 920°C or more, roll temperature of 680°C and then cut to 3.2 mm^t. Afterwards the metal was cold rolled to 0.8 mm^t and after consecutive annealing for 1 minute at an average temperature of 800°C, a 1% rolling adjustment was performed to produce the test sample cold-rolled sheet. A 10 mm × 110 mm test sample was utilized for the r value, and the width and sheet thickness measured when a tensile strain of 0 to 15% was applied. The burr height was measured and evaluated at the edges after punching a circular shape of 10 mm diameter in 0.8 mm^t cold rolled steel with a clearance of 9%. The surface of the cold rolled steel sheet was examined visually for surface defects and evaluated by finding the percent of surface defects occurring in a fixed length.

As Figs. 1 and 2 clearly show, when the sulfur content is less than 0.01% the burr height during punching is

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extremely large and the object of this invention cannot be achieved. However when the sulfur content exceeds 0.025%, surface defects drastically increase again thwarting the object of the invention. However when the sulfur content is 0.01% or more, and 0.025% or less, the surface defects and burr height can be limited as much as possible and a high level r value can be obtained.

The data in Figs. 1 and 2 shows the effect the sulfur content exerts on physical characteristics of the cold rolled steel. This effect is largely the same as that for the hot rolled steel before cold rolling was performed. Setting the sulfur content within a range of 0.001 to 0.025% was verified as yielding hot rolled steel sheet with superior punch processability and no surface defects.

N: 0.01% or less

Nitrogen combines with titanium to produce TiN but this TiN has virtually no effect in improving punch processability. Nitrogen, as is the case with carbon, weakens the stretch-flangeability and tensile properties of the steel and therefore an upper limit of 0.01% was set to avoid these drawbacks.

Ti: 0.2% or less

Titanium is one of the most important elements because of the $Ti_4C_2S_2$ or ($Ti_4C_2S_2$ and TiS) precipitates produced in the steel and the improvement provided in punch processability and stretch-flangeability. The lower limit

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value for titanium content must be determined according to the nitrogen, sulfur and carbon content in the steel. However a maximum content achieving the effect of the invention is 0.2%, a higher content would not be cost effective. Preferably the titanium content is 0.15% or less.

Besides forming $Ti_4C_2S_2$ and TiS , titanium can also according to conditions form with nitrogen in solid solution to produce TiN , or with carbon in solid solution to produce TiC . The lower limit value of titanium must be determined by taking into account their respective effects and according to the carbon, sulfur and nitrogen content based on formula (1) below. When forming hot rolled steel this value should be in the range of 1.0 to 3.0 and for cold rolled steel should be in the range of 0.8 to 4.0 with the content of each element adjusted according to the relation with the other element.

$$(Ti^*/48)/(C/12 + S/32) \quad \text{----- Formula (1)}$$

$$\text{However, } Ti^* = Ti - (48/14)N$$

However, for hot rolled steel, when the value is less than that in formula 1, the amount of titanium is insufficient for bonding with the carbon and sulfur and the amount is insufficient for producing $Ti_4C_2S_2$ needed for improving the punch processability. However when the value exceeds 3.0 and the carbon content is excessive, the amount of carbon in solid solution increases, or when the sulfur content is excessive, MnS and large TiS is produced so that in either of these cases the ductility or elongation is

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poor and insufficient forming and stretch-flangeability processing are obtained. In cold rolled steel, when the value from the above formula (1) is less than 0.8, the amount of titanium for bonding with the carbon and sulfur is insufficient and the amount of $Ti_4C_2S_2$ needed for improving the punch processability is inadequate. However when this value exceeds 4.0 and the carbon content is excessive, then the carbon in solid solution will increase, or when the sulfur is excessive, MnS is produced so that in either of these cases the ductility or elongation is poor and insufficient forming and stretch-flangeability processing are obtained. In the case of cold rolled steel, there is some tolerance allowed in the value obtained from formula (1) because at the end of hot rolling performed prior to the cold rolling, even if some large (rough) TiS is produced, the subsequent cold rolling will break down the TiS into finer particles so there will be no significant problem due to effects on surface precision.

Al: 0.1% or less

Aluminum is an element whose use is essential and unavoidable as an antioxidant. Too high an aluminum content is a source for non-metallic Al_2O_3 based inclusions which exerts adverse effects on mechanical characteristics and machining so that aluminum content is limited to 0.1% or less.

When the steel sheet of this invention having a precipitates constituting mainly $Ti_4C_2S_2$ (or $Ti_4C_2S_2$ and

TiS) and a size within a range of 1,000 to 10,000Å is included in specific proportions in the steel, the machining , punching and stretch-flangeability are improved remarkably with no adverse effects on forming. However the steel sheet manufacturing conditions, and further the temperature during heat rolling and coiling conditions are essential in producing the optimal amounts of this precipitate of mainly $Ti_4C_2S_2$ in the steel. It has been confirmed that to attain the object of the invention, it will prove sufficient to heat a steel slab that satisfies the above mentioned requirements for chemical constituents, to within a range of 1,100 to 1,200°C, complete heat form rolling within the temperature range (Ar_3 transformation temp. +80°C) to (Ar_3 transformation temp. -40°C), followed by coiling at a temperature range between 600 to 700°C.

If the heating temperature at this time is below 1,100°C, then the amount of MnS produced increases and the amount of $Ti_4C_2S_2$ precipitates in the steel will be inadequate. If the heat exceeds 1,200°C virtually all of the precipitates dissolves and the correct amount of $Ti_4C_2S_2$ precipitates cannot be obtained. Also, when the temperature during heat form rolling exceeds 700°C, the $Ti_4C_2S_2$ based precipitates changes into FeTiP based precipitates and the improved machinability and punch processability desired of this invention cannot be obtained. No particular value is set as a lower limit for the coiling temperature but if too low then Ti based precipitates is not produced or even if produced the TiC as

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$Ti_4C_2S_2$ precipitates cannot be obtained, so that a temperature of $500^{\circ}C$ or higher is preferable. If the coiling temperature is too low when manufacturing cold rolled steel sheet, then the TiC precipitate will be incomplete and a residual amount of carbon in solid solution will cause the r value for annealing to deteriorate, so that the coiling temperature is preferably set within a range of 600 to $700^{\circ}C$.

As long as the above heating temperatures and coiling temperatures are maintained, there will be little effect on the amount of $Ti_4C_2S_2$ produced even if the heat roll finishing temperature varies somewhat. However, in order to achieve both smooth heat rolling and heat rolled steel sheet having stable mechanical characteristics and product shape, the finishing temperature is preferably set within a range of (Ar_3 transformation temp. $+80^{\circ}C$) to (Ar_3 transformation temp. $-40^{\circ}C$). However when the heat roll finishing temperature is too low, $FeTiP$ is produced. This $FeTiP$ and the carbon in solid solution causes the press-forming characteristics to worsen. Conversely, when the heat roll finishing temperature is too high, the amount of large (rough) TiS produced increases which in particular can be a source of surface defects during use of the hot rolled steel sheet. However, when this is cold rolled and used as cold rolled steel sheet, the above mentioned large (rough) TiS is broken down into finer pieces in the cold rolling process and thus will not be a source of surface defects. These TiS precipitates are an effective

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constituent for improving the punch processability when making actual use of the cold rolled steel sheet.

There are no particular limits on the conditions for cold rolling and annealing performed after the heat rolling however, a preferred size and dispersion amount of $Ti_4C_2S_2$ precipitates produced in the heat rolling process for maintaining the desired effects is a downward pressure setting of 60 to 85% and a temperature of 700°C or more and the Ac_3 point or below in the later annealing process, with a temperature range setting of 750 to 850°C being even more preferable. If the above mentioned downward pressure setting is used for cold rolling, even if the large (rough) TiS based precipitates is present internally after completion of hot rolling, these precipitates will be broken down into finer pieces in the cold rolling process and thus will not be a source of surface defects and the precipitates will prove an effective element in obtaining improved punch processability.

The hot rolled steel sheet or cold rolled steel sheet thus obtained may be used as is, or further electrically galvanized or fused zinc galvanized for anti-rust purposes, or chemical processing such as acid-base processing or chromate processing performed. Additionally, organic plastic coating or similar processing will of course prove effective as surface treatments.

There are few cases of a steel plate chassis actually being used without having some kind of surface coating. This is because use of cold or hot rolled steel sheet as

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is, generates red rust in a short time in the outside atmosphere. This rust eats into the metal not only reducing its strength but exerting adverse effects on the drive sections and electrical circuitry due to loose rust powder. Use of a surface treatment is an extremely effective method in preventing the generation of rust. This invention utilizes zinc alloy electrical galvanizing which displays a superior effect in preventing rust without exerting adverse effects on the forming and punch processability.

Various galvanizing methods are available such as fusible galvanizing performed by soaking the steel sheet in fusible zinc in solution, electrical galvanizing for precipitating metallic zinc on the steel sheet surface by applying a charge through electrolytic fluid containing zinc ions, and the steam adhesion galvanizing method for making zinc in a vaporized state adhere to the surface of the steel sheet. However, in this invention utilization of the electrical galvanizing method is desirable because of the fine appearance and even distribution of material in the galvanized layer along with the fact that there are no surface defects even though the material adhering is relatively thin. In order for this electrically galvanized layer to be effective in preventing rust, the galvanized layer should adhere in a thickness of 3 g/m^2 or more. If this adhering layer is insufficient then anti-corrosion properties cannot be guaranteed or the plastic coating formed over the galvanized layer must be made excessively

thick and the electrical grounding property is lost. From the viewpoint of corrosion resistance there is no particular limit on the adhering galvanized layer thickness but when it exceeds 40 g/m^2 an anti-corrosive effect may not be obtained even if the layer is made excessively thick. If the galvanizing process time is too long or the sealing of the galvanized layer is too low then peeling of this layer may occur so it should be limited to a thickness of 40 g/m^2 .

The zinc electrically galvanized layer used here, besides pure zinc galvanizing also includes zinc-based galvanizing containing Ni, Co and Fe along with the zinc, or may be a lower coating of this same pure zinc galvanizing or zinc-based galvanizing or perhaps a different type of pre-galvanizing, in zinc galvanizing types where the zinc content is 50% or more by weight.

Forming of the zinc electrically galvanized layer is by itself, sufficient to obtain the objective of anti-rust in the steel plate. To use this as a material for items such as chassis, resistance to fingerprints is preferable in addition to preventing rust on the galvanized layer itself. An extremely effective method to achieve this is to further apply a plastic coating over the zinc electrically galvanized layer. The preferred adherence amount for the plastic coating is within a range of 0.1 to 2.5 g/m^2 . When the amount of plastic coating that adheres is insufficient, satisfactory corrosion resistance and fingerprint resistance cannot be obtained. Conversely when

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the amount is too large, the electrical conductivity of the top layer decreases and the grounding is extremely poor.

There are no particular limits on the constituent types of the resin composing the plastic layer but most typically these are ethylene polymer resin, polyester resin, polyvinyl resin, acrylic resin, urethane resin, or polyamide resin containing polymers of epoxy resin or ethylene non-saturated carboxylic acid. These resin types can be used alone or mixed from two or more types as needed. Forming favorable resin constituents is recommended by altering the functional groups within these resins by the usual methods or reinforcing them with cross-link solution. Furthermore, organic or inorganic silicon compounds can be applied for instance to improve resistance to fingerprints, or wax constituents can be added to the resin in small amounts to improve surface type scuffing characteristics during press processing, or wax constituents can be introduced in reformed elements in functional groups in the resin.

The plastic coating is preferable as a protective surface layer after press processing for providing resistance to corrosion and resistance to fingerprints. For this purpose a resin mix of one or more types of epoxy resin, ethylene polymer resin, polyester resin, and urethane resin are preferable as base resins.

Preferably the anti-corrosiveness of the plastic coating is further improved adding for instance silica particles such as of silicon inorganic compounds in an

amount of approximately 5% or more by weight to the base resin. However when the silica particle content is too large, it functions as an anti-slip material, raising the friction index of the coating and lowering its lubricating qualities. A further drawback is a decrease in resistance to corrosion that appears after machining so that the content should be about 30% or less by weight, or more preferably 10% or less by weight.

The effect from these silica particles is best obtained by using a particle size of 1 to 20 μm . In other words, the smaller the silica particles the finer the coating becomes and the sealing thus improves. Consequently the corrosion resistance of the coating and coatability (layer precipitation) improves, however if the particles smaller than 1 μm are used, a still greater effect may not be achieved, so that a lower particle size limit of 1 μm is sufficient. Conversely, when the size exceeds 20 μm , the surface of the coating is rough, a fine membrane cannot be formed, and the resistance to corrosion is also poor. Thus a preferable particle size is 4 to 6 μm . This kind of silica particle is known as colloidal silica and is commercially obtainable for instance under the brand name "Snow-Tex XS or Snow-Tex SS" (both manufactured by Nissan Kagaku Kogyo : commercial name).

There are no limits whatsoever on the method for forming the plastic coating. After forming an electrical galvanized layer by the usual methods on one side or both sides of the hot rolled steel sheet or the cold rolled

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steel sheet manufactured by a method as related previously, the plastic coating may be applied over the galvanized surface by the desired method such as roll coating, dip coating or spray coating. After performing chemical treatment such as chromate processing or acid-base processing of the surface of the galvanized steel sheet, forming of the plastic layer at this time will prove effective in enhancing the sealing of the galvanized layer with the plastic coating which is of course included within the technical scope of this invention.

EXAMPLES:

Specific examples of the structure and effect of the invention are described in the embodiments listed here yet this invention is not limited by the embodiments described hereafter and may be further changed as appropriate within the applicable spirit of the invention and the foregoing is included within the technical scope of this invention.

The performance tests employed in the following embodiments, for the tensile properties, machinability, punch processability and verification methods for the type and amount of precipitates in the steel plate are described below.

Verification of type and amount of precipitates:

Observation was performed by the replica extraction method using a transparency type electron microscope. At 10,000 times magnification, the amount of the precipitates was

found within a visual range of 0.15 mm^2 and this then counted to obtain the precipitates amount within 1 mm^2 .

Tensile properties:

A test piece setup for JIS5 was used in the tensile tests. The yield point (YP), tensile strength (TS), elongation (El) and work hardening coefficient (n value) were each evaluated. After further processing at 100°C for 60 minutes, non-aging properties (A.I) was evaluated from the amount of rise in the yield point.

r value:

A test piece of $10 \text{ mm} \times 110 \text{ mm}$ was utilized. The width and thickness of the piece was measured when a tensile strain of 0% and 15% was applied.

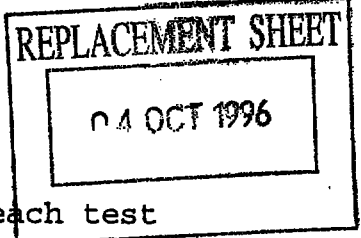
Punch Processability:

A circular pattern with a clearance of approximately 12% and diameter of 30 mm was punched and the height of the burrs occurring on the edge were measured and evaluated.

Machinability:

A pipe with an outer diameter of 60 mm was fabricated utilizing the high frequency induction heat welding method for each test piece sheet. Cutting was carried out at a cutting speed of 125 m/minute, and notching speed of 0.06 m/revolution. The cut-through repetitions (for tool life) and swarf (cutting waste) status (GOOD = small, curl-shaped swarf, DEFECT = long curl-shaped swarf) were evaluated.

Stretch-flanging:



A hole 20 mm in diameter was punched in each test piece sheet. The punched hole (dia./mm) was widened with a conical punch at an apex angle of 30 degrees until the crack penetrated through the sheet thickness. The hole expansion rate was found by means of the formula below, from the hole diameter (df:mm) at that time, and the stretch-flangeability evaluated.

$$\text{Hole expansion rate} = [(df-di) / di] \times 100 (\%)$$

First Embodiment

After heating the steel slab with the chemical compositions shown in Table 1, to 1180°C, a hot rolling finishing temperature of approximately 920°C and a coiling temperature of 630°C was set, and hot rolling performed to obtain hot rolled steel sheet with a thickness of 3.2 mm.

The precipitates type and amount produced in the steel obtained from the hot rolling was investigated along with the tensile properties, machinability and punch processability. The results are shown in Table 2.

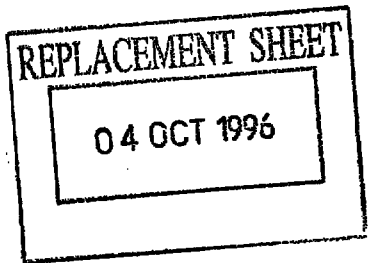


Table 1

Steel type	Chemical compositions (mass%)									Ar3 point	Precipitates figure*1 (piece/mm ²)	Remarks
	C	Si	Mn	P	S	Al	Ti	N	(Ti*/48) / (C/12 + S/32)			
A	0.0052	0.02	0.32	0.013	0.017	0.032	0.078	0.0067	1.2	892	2.1×10 ⁴	*2
B	0.0031	0.02	0.46	0.035	0.014	0.033	0.048	0.0027	1.2	877	1.6×10 ⁴	*2
C	0.0033	0.01	0.63	0.015	0.022	0.033	0.070	0.0028	1.3	865	3.7×10 ⁴	*2
D	0.0032	0.01	0.94	0.016	0.018	0.034	0.076	0.0036	1.6	857	4.2×10 ⁴	*2
E	0.0129	0.02	0.37	0.016	0.008	0.032	0.115	0.0059	1.5	883	3.9×10 ³	*3
F	0.0017	0.44	0.44	0.091	0.007	0.031	0.085	0.0041	4.1	874	3.2×10 ³	*3
G	0.0044	0.02	0.17	0.016	0.009	0.028	0.076	0.0045	2.0	905	2.3×10 ³	*3
H	0.0035	0.01	1.15	0.014	0.006	0.031	0.066	0.0037	2.3	825	2.7×10 ³	*3
I	0.0032	0.01	0.44	0.088	0.008	0.036	0.074	0.0108	1.5	881	4.1×10 ⁴	*3
J	0.0028	0.02	0.46	0.013	0.005	0.036	0.039	0.0034	1.4	868	2.8×10 ⁴	*3
K	0.0045	0.01	0.44	0.018	0.031	0.029	0.106	0.0045	1.4	876	2.3×10 ⁵	*3
L	0.0055	0.01	0.42	0.015	0.016	0.031	0.055	0.0056	0.8	875	2.4×10 ⁴	*3
M	0.0007	0.01	0.45	0.021	0.022	0.035	0.077	0.0032	1.8	879	3.1×10 ³	*3

*1: Quantity of precipitates with size of 1000 to 10000Å.
Steel types F and I have precipitates of FeTiP alloy
and the other steel types are Ti₄C₂S₂ type alloy.

*2: Example of the present invention.

*3: Comparison example.

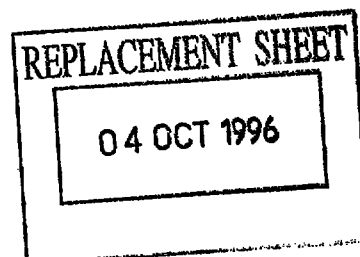


Table 2

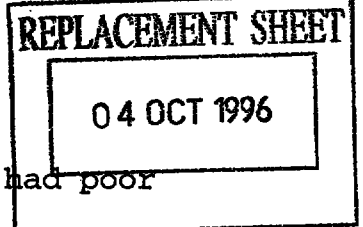
Steel type	Tensile properties				Punching characteristics	Machinability		Remarks
	YS (N/mm ²)	TS (N/mm ²)	n value	E1 (%)	Burr height (μm)	Tool life (times)	Cutting grit disposal	
A	163	315	0.247	53	34	56	o	*1
B	158	324	0.251	53	24	53	o	*1
C	159	328	0.242	52	29	48	o	*1
D	190	385	0.236	45	25	46	o	*1
E	184	342	0.222	45	44	37	x	*2
F	224	436	0.203	36	38	29	x	*2
G	162	318	0.242	50	65	39	x	*2
H	214	355	0.222	45	54	41	x	*2
I	221	359	0.219	44	46	26	x	*2
J	153	317	0.244	49	57	17	x	*2
K	164	323	0.231	46	37	43	o	*2
L	190	314	0.196	45	40	45	o	*2
M	143	297	0.250	51	63	21	x	*2

*1: Example of the present invention

*2: Comparison example

Results from Tables 1 and 2 can be interpreted as follows.

Steel types A, B and C are soft steel while steel type D is high strength steel that satisfy the stipulated conditions for this invention. All of these types, along with having superior tensile properties also provide superior performance for punching and machining .



In contrast, steel types E through J all had poor punch processability and machinability due to an insufficient sulfur content. In addition, the steel type E has too high a carbon content so tensile properties are poor because TiC is produced. The steel type H had too high a manganese content so punch processability was poor because MnS is produced. The steel type M had an insufficient amount of carbon so that tensile properties are poor and further has poor punch processability because an inadequate amount of $Ti_4C_2S_2$ precipitates is produced. The following is not shown in Table 2 however, because the silicon content in steel type F is too large, a silicon oxide layer during the electrical galvanizing caused variations in the galvanized layer and the sealing of the galvanized layer was poor. In steel type K it was verified that, because the sulfur content was too large, the tensile properties were bad even though the punch processability was satisfactory, furthermore surface defects such as blisters and slivers were verified on the steel sheet surface after rolling. In steel types F and L, the balance between the amount of Ti and the amount of carbon and steel was poor, so that the conditions in the above mentioned formula (1) could not be satisfied. Consequently besides the tensile properties balance being bad, the punch processability was poor and the resistance to aging unsatisfactory.

Second Embodiment

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The steel type B (877°C at Ar₃ point) shown in Table 1 was utilized. The hot form rolling was performed in the same way as for the first embodiment except for the heating temperature, finishing temperature and coiling temperature which were changed as shown in Table 3. The hot rolled steel sheet was manufactured to a width of 3.2 mm. Along with investigating the precipitates types and amount for each test piece exactly as in the first embodiment, along with the tensile properties, and punch processability. The results are shown in Table 4.

Table 3

Steel type	Hot rolling condition (°C)			Precipitates figure and status (piece/mm ²)	Remarks
	Heating temp.	Finishing temp.	Coiling temp.		
B1	1230	935	610	3.4×10 ³ TiS type	*1
B2	1180	920	630	1.6×10 ⁴ Ti ₄ C ₂ S ₂ type	*2
B3	1145	915	620	1.0×10 ⁴ Ti ₄ C ₂ S ₂ type	*2
B4	1070	930	605	4.7×10 ³ MnS type	*1
B5	1175	995	630	3.5×10 ³ MnS type	*1
B6	1170	895	630	3.6×10 ⁴ Ti ₄ C ₂ S ₂ type	*2
B7	1180	825	625	2.7×10 ³ FeTiP type	*1
B8	1190	915	735	3.8×10 ³ FeTiP type	*1
B9	1175	930	580	1.9×10 ⁴ Ti ₄ C ₂ S ₂ type	*2
B10	1185	920	525	4.4×10 ⁴ Ti ₄ C ₂ S ₂ type	*2

*1: Comparison example

*2: Example of the present invention

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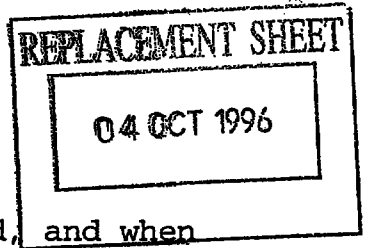
Table 4

Steel type	Tensile properties				Punching characteristics	Machinability		Remarks
	YS (N/mm ²)	TS (N/mm ²)	n value	E1 (%)	Burr height (μm)	Tool life (times)	Cutting grit disposal	
B1	163	327	0.249	51	44	46	×	*1
B2	158	324	0.251	53	24	53	○	*2
B3	157	325	0.247	52	27	49	○	*2
B4	155	319	0.244	49	41	37	×	*1
B5	149	324	0.213	47	43	38	×	*1
B6	159	322	0.254	53	26	55	○	*2
B7	154	317	0.196	43	32	46	Δ	*1
B8	162	320	0.218	47	38	30	×	*1
B9	153	328	0.246	43	31	50	○	*2
B10	166	336	0.237	48	35	44	○	*2

*1: Comparison example

*2: Example of the present invention

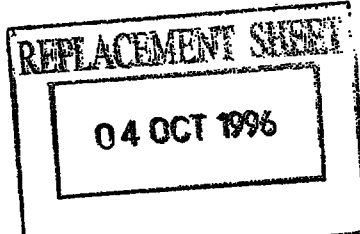
The symbols B1 through B4 in Tables 3 and 4 show the suitable temperature ranges for the hot roll finishing temperature and coiling temperature. In particular, when investigating the effect of the heating temperature, it was found in steel types where heating was performed in a range from 1,100 to 1,200°C (symbols B2, B3) that Ti₄C₂S₂ based precipitates was produced in suitable sizes and amounts and the tensile properties and punch processability were superior in each case. In contrast, when the heating temperature in the comparison sample (symbol B1) exceeded



1,200°C, precipitates mainly of TiS were formed, and when the temperature dropped below 1,100°C in the comparison sample (symbol B₄) a precipitate mainly of MnS was formed with the punch processability and machinability being poor in both cases.

The symbols B₅ through B₇ show the suitable temperature ranges for heating temperature and coiling temperature. In particular, when investigating the effect of finishing temperature, it was found that in steel types where heating was performed in a range from 1,100 to 1,200°C (symbols B₆) $Ti_4C_2S_2$ based precipitate was produced in suitable sizes and amounts and the tensile properties and punch processability were superior in each case. In contrast, when finishing temperature in the comparison sample (symbol B₅) was too high, precipitates mainly of MnS were formed, and when finishing temperature was too low in the comparison sample (symbol B₇) precipitates mainly of $FeTiP$ were formed with the punch processability being poor in both cases.

The symbols B₈ through B₁₀ show the suitable temperature ranges for heating temperature and the finishing temperatures. In particular, when investigating the effect of the coiling temperature, it was found that in steel types where the coiling temperature was in the correct range (symbols B₁₀, B₁₁) $Ti_4C_2S_2$ based precipitates was produced in suitable sizes and amounts and the tensile properties and punch processability were superior in each case. In contrast, when the coiling temperature in the



comparison sample (symbol Bg) was too high, precipitates mainly of FeTiP were formed and satisfactory machinability could not be obtained.

Third Embodiment

After steel slab with the chemical compositions shown in Table 5 was heated to 1180°C, a finishing temperature of approximately 920°C and a coiling temperature of 630°C was set, and hot rolling then performed. After obtaining hot rolled steel with a thickness of 3.2 mm, each hot rolled steel sheet was then cold rolled to a thickness of 0.8 mm. After performing consecutive annealing for 1 minute at 800°C, 1 percent temper rolling was carried out. The respective tensile properties and punch processability were investigated and the results obtained are given in Table 5.

Along with investigating the precipitates types and amounts produced in the cold rolled steel obtained above, the tensile properties, punch processability, and stretch-flangeability were also investigated and the results obtained are shown in Table 6.

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Table 5

type	Chemical compositions (mass%)										Ar ₃ point	Precipitates figure*1 (piece/mm ²)	Remarks
	C	Si	Mn	P	S	Al	Ti	N	B	(Ti*/48) / (C/12 + S/32)			
A	0.0052	0.02	0.32	0.013	0.017	0.032	0.078	0.0067	-	1.2	892	4.4×10 ⁴	*2
B	0.0031	0.02	0.46	0.035	0.014	0.033	0.048	0.0027	-	1.2	877	3.1×10 ⁴	*2
C	0.0033	0.01	0.63	0.015	0.022	0.033	0.070	0.0028	-	1.3	865	7.7×10 ⁴	*2
D	0.0032	0.01	0.94	0.016	0.018	0.034	0.076	0.0036	-	1.6	857	8.7×10 ⁴	*2
E	0.0129	0.02	0.37	0.016	0.008	0.032	0.115	0.0059	-	1.5	883	7.8×10 ³	*3
F	0.0017	0.44	0.44	0.091	0.007	0.031	0.085	0.0041	-	4.1	874	6.5×10 ³	*3
G	0.0044	0.02	0.17	0.016	0.009	0.028	0.076	0.0045	-	2.0	905	4.1×10 ³	*3
H	0.0035	0.01	1.15	0.014	0.006	0.031	0.066	0.0037	-	2.3	825	4.6×10 ³	*3
I	0.0032	0.01	0.44	0.088	0.008	0.036	0.074	0.0108	-	1.5	881	8.2×10 ³	*3
J	0.0028	0.02	0.46	0.013	0.005	0.036	0.039	0.0034	-	1.4	868	6.9×10 ³	*3
K	0.0045	0.01	0.44	0.018	0.031	0.029	0.106	0.0045	-	1.4	876	6.3×10 ⁵	*3
L	0.0039	0.01	0.55	0.013	0.043	0.032	0.125	0.0036	-	1.4	872	9.8×10 ⁵	*3
M	0.0050	0.01	0.46	0.014	0.017	0.033	0.050	0.0058	-	0.7	881	4.3×10 ³	*3
N	0.0007	0.01	0.45	0.021	0.022	0.035	0.077	0.0032	-	1.8	879	5.2×10 ³	*3
O	0.0038	0.01	0.36	0.011	0.019	0.037	0.081	0.0031	0.005	1.6	891	2.9×10 ⁴	*2

*1: Quantity of precipitates with size of 1000 to 10000Å.
Steel types F and I have precipitates of FeTiP alloy
and the other steel types are Ti₄C₂S₂ type alloy.

*2: Example of the present invention

*3: Comparison example

Table 6

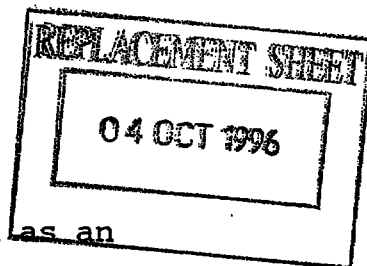
Steel type	Tensile properties				Punching characteristics	Stretch-flange-ability	Remarks
	YS (N/mm ²)	TS (N/mm ²)	E1 (%)	r value	Burr height (μm)	Hole expansion limit (%)	
A	165	316	52	2.12	23	203	*1
B	158	327	51	2.03	17	216	*1
C	157	331	51	1.97	20	198	*1
D	188	382	45	1.95	17	206	*1
E	186	344	43	1.62	32	175	*2
F	221	430	33	1.74	28	151	*2
G	158	318	47	1.80	45	197	*2
H	222	359	43	1.66	39	189	*2
I	224	356	42	1.72	33	174	*2
J	155	321	47	1.84	42	205	*2
K	164	327	44	1.85	36	162	*2
L	168	322	42	1.77	35	133	*2
M	193	213	43	1.43	39	158	*2
N	143	298	50	1.99	51	194	*2
O	183	322	49	1.94	16	203	*1

*1: Example of the present invention

*2: Comparison example

Results from Tables 5 and 6 can be interpreted as follows.

In the embodiment, steel types A, B and C are soft steel while steel type D is high strength steel that satisfy the stipulated conditions for this invention.



Steel type O is an embodiment including boron as an element. All of these types, along with having superior tensile properties also provide superior performance for punching and machining.

In contrast, steel types E through J all had poor punch processability due to insufficient sulfur content. In addition, the steel type E had too high a carbon content so tensile properties are poor because TiC is produced. The steel type H had too high a manganese content so that tensile properties and stretch-flangeability is poor because MnS is produced. The steel type M had an insufficient amount of carbon so that tensile properties are poor and further had poor punch processability and stretch-flangeability because an inadequate amount of $Ti_4C_2S_2$ precipitates are produced. The following is not shown in Table 2 however, because the silicon content in steel type F is too large, a silicon oxide layer formed during the electrical galvanizing caused variations in the galvanized layer and the sealing of the galvanized layer was poor. In steel type K it was verified that, because the sulfur content was too large, the tensile properties were bad even though the punch processability was satisfactory, furthermore surface defects such as blisters and slivers were verified on the steel sheet surface after rolling. In steel types F and M, the balance between the amount of Ti and the amount of carbon and steel was poor so that the conditions in the above mentioned formula (1) could not be satisfied and consequently besides the tensile

properties balance being bad, the punch processability and stretch-flangeability was poor and the resistance to aging unsatisfactory.

Fourth Embodiment

The steel type B (877°C at Ar₃ point) shown in Table 5 was utilized. The hot rolling was performed in the same way as for the third embodiment except for the heating temperature, hot rolling finishing temperature and coiling temperature which were changed as shown in Table 7. The hot rolled steel sheet was manufactured to a width of 3.2 mm and further cold rolled to a thickness of 0.8 mm. After performing consecutive annealing for 1 minute at 800°C, 1 percent temper rolling was carried out to obtain the cold rolled steel. The respective tensile properties, stretch-flangeability and punch processability were investigated and the results obtained are shown in Table 8.

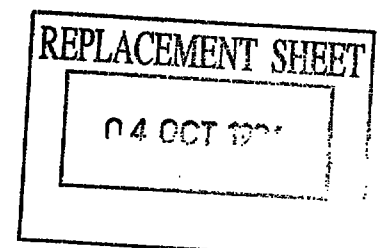
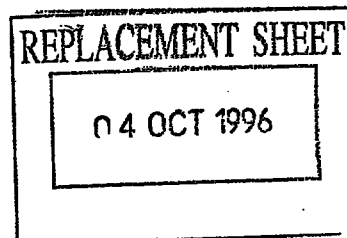


Table 7

Steel type	Hot rolling condition (°C)			Precipitates figure and status (piece/mm ²)	Remarks
	Heating temp.	Finishing temp.	Coiling temp.		
B1	1230	935	610	6.4×10^5 TiS type	*1
B2	1180	920	630	3.1×10^4 Ti ₄ C ₂ S ₂ type	*2
B3	1145	915	620	6.3×10^4 Ti ₄ C ₂ S ₂ type	*2
B4	1070	930	605	8.7×10^3 MnS type	*1
B5	1175	995	630	5.5×10^5 MnS type	*1
B6	1170	895	630	5.2×10^4 Ti ₄ C ₂ S ₂ type	*2
B7	1180	850	625	5.1×10^3 FeTiP type	*1
B8	1190	915	735	3.8×10^3 FeTiP type	*1
B9	1180	925	680	3.6×10^4 Ti ₄ C ₂ S ₂ type	*2
B10	1175	930	580	8.8×10^3 Ti ₄ C ₂ S ₂ type	*1

*1: Comparison example

*2: Example of the present invention



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Table 8

Steel type	Tensile properties				Punching character- istics	Stretch- flange- ability	Remarks
	YS (N/mm ²)	TS (N/mm ²)	El (%)	r value	Burr height (μ m)	Hole expansion limit (%)	
B1	164	326	49	1.81	32	179	*1
B2	156	327	51	2.03	13	216	*2
B3	155	322	50	2.11	19	196	*2
B4	161	323	47	1.88	36	181	*1
B5	157	321	45	1.79	34	186	*1
B6	156	319	52	2.06	18	223	*2
B7	152	315	42	1.65	26	177	*1
B8	160	328	45	1.61	30	175	*1
B9	150	323	50	1.94	21	194	*2
B10	178	335	42	1.60	30	173	*1

*1: Comparison example

*2: Example of the present invention

The symbols B₁ through B₄ in Tables 7 and 8 show the suitable temperature ranges for the finishing temperature and coiling temperature. In particular, when investigating the effect of the heating temperature, it was found in steel types where heating was performed in a range from 1,100 to 1,200°C (symbols B₂, B₃) the Ti₄C₂S₂ based precipitates was produced in suitable sizes and amounts and the tensile properties, stretch-flangeability and punch processability were superior in each case. In contrast, when the heating temperature in the comparison sample

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(symbol B₁) exceeded 1,200°C, precipitates mainly of MnS were formed, and when the temperature dropped below 1,100°C in the comparison sample (symbol B₄) precipitates mainly of TiS were formed with the punch processability being poor in both cases.

The symbols B₅ through B₇ show the suitable temperature ranges for the heating temperature and coiling temperature. In particular, when investigating the effect of the finishing temperature, it was found that in steel types where heating was performed in a range from 1,100 to 1,200°C (symbols B₆) the Ti₄C₂S₂ based precipitates was produced in suitable sizes and amounts and the tensile properties, stretch-flangeability and punch processability were superior in each case. In contrast, when the finishing temperature in the comparison sample (symbol B₅) was too high, precipitates only of MnS were formed, and when the heat roll finishing temperature was too low in the comparison sample (symbol B₇) precipitates mainly of FeTiP were formed with the punch processability being inadequate in both cases.

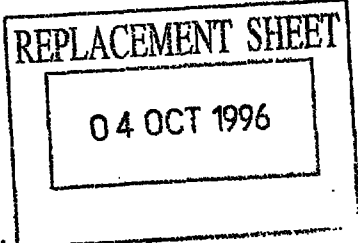
The symbols B₈ through B₁₀ show the suitable temperature ranges for the heating temperature and the heat roll finishing temperatures. In particular, when investigating the effect of the coiling temperature, it was found that in steel types where the coiling temperature was in the correct range (symbols B₉) the Ti₄C₂S₂ and the TiS based precipitates was produced in suitable sizes and amounts and the tensile properties, stretch-flangeabilities

and punch processability were superior in each case. In contrast, when the coiling temperature in the comparison sample (symbol Bg) was too high, precipitates mainly of FeTiP was formed and satisfactory stretch-flangeability could not be obtained. When the coiling temperature in the comparison sample (symbol B10) was too low, the $Ti_4C_2S_2$ and the TiS based precipitates were not produced in sufficient amounts and the punch processability and stretch-flangeability performance was somewhat low.

Fifth Embodiment

Cold rolled steel sheets obtained utilizing steel types A, B and C from among the cold rolled steel sheet of the third embodiment were galvanized on the surface in accordance with the usual methods to form a galvanized layer of 1 to 50 g/m². Chromate treatment was then performed so that the chromium precipitate formed over the galvanized layer is converted to metallic chromium at 10 mg/m².

A resin base of ethylene, ester or urethane resin was used for mixing with colloidal silicon particles converted to solid type, of 4 to 6 μ m in size and in a 10% portion mix in the resin material applied at 0.05 to 3 g/m² in order to obtain the surface treated steel sheet. The resistance to corrosion, resistance to fingerprint and grounding were evaluated and the results are shown in Table 9.



Corrosion Resistance:

A salt spray test was performed according to the methods listed in JIS Z 2371 and the time for generation of 1% white rust evaluated.

O = 240 hours or more X = less than 240 hours

Resistance to Fingerprints:

The test piece was soaked in a 50% white-colored vaseline solution at 40°C and then extracted.

Discoloration on the vaseline coated portion and the non-coated portions was measured and evaluated. The color difference (ΔE) between the vaseline coated and non-coated portions was "3 or less" thus showing good resistance to fingerprints.

O = ΔE of 3 or less X = more than ΔE

Grounding:

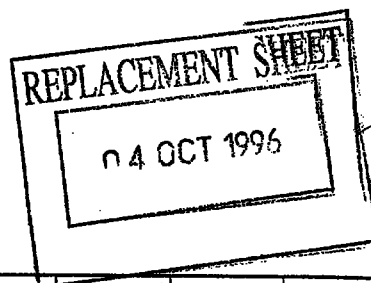
The conductivity of the surface of the test piece was measured in surface resistance across tester terminals spaced 100 mm apart and the results evaluated.

O = surface resistance of 200 ohms or less X = surface resistance of 200 ohms or more

Overall Evaluation:

O = Satisfactory X = Unsatisfactory

Table 9



No.	Steel type	Zn adhering amount (g/m ²)	Resin type *)	Resin adhering amount (g/m ²)	Corrosion resistance	Finger-print resistance	Grounding	Overall evaluation	Remarks
1	A	15	Ethylene	0.5	o	o	o	o	Embodiment
2	A	10	Ethylene	0.5	o	o	o	o	
3	B	20	Ethylene	0.1	o	o	o	o	
4	B	40	Urethane	0.3	o	o	o	o	
5	C	30	Ester	2.5	o	o	o	o	
6	B	2	Ethylene	0.05	x	x	o	x	Comparison example
7	B	20	Urethane	3.0	o	o	x	x	
8	B	20	None	—	x	x	o	x	
9	C	20	Polyester	0.05	x	x	o	x	

*) : Details on resin type

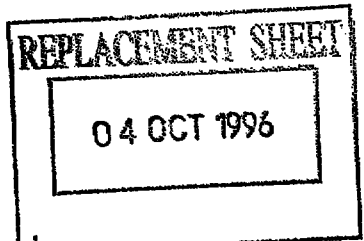
Ethylene: Ethylene polymer resin containing 20% acrylic acid by weight consisting of ethylene non-saturated carboxylic acid

Ester: Polyester resin, product brand name of "BYRON 20SS" made by Toyo Boseki Co.

Urethane: Polyurethane resin, product brand name of "SUPERFLEX" made by Daiichi Kogyo Chemical Co.

Results from Table 7 can be interpreted as follows.

The chemical compositions, and the amounts of the electrically galvanized layer and plastic coating steel material of embodiments No. 1 through 5 satisfied the specified conditions of this invention. An extremely

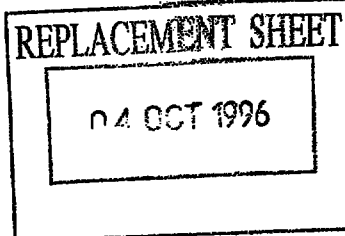


superior effect was also obtained for the corrosion resistance, resistance to fingerprints, and grounding.

In contrast, No. 6 had poor corrosion resistance and poor resistance to fingerprints due to insufficient adherence amounts of the electrically galvanized layer and the plastic coating. No. 7 had poor grounding because the plastic coating was too large. No 8 had poor corrosion resistance and poor resistance to fingerprints because the plastic layer had not been applied. No. 9 was unable to provide satisfactory corrosion resistance and resistance to fingerprints because the amount of plastic coating was insufficient.

Effect of the Invention:

This invention is comprised as described above and along with the composition elements of the steel material, the content in particular of the titanium, sulfur, manganese and nitrogen are regulated and the interrelation of the sulfur, nitrogen and carbon amounts with the titanium amount suitably controlled to produce $Ti_4C_2S_2$ precipitates in the proper amounts and size. This allows thin steel plate with extremely excellent punch processability to be provided without loss to the forming or the mechanical properties of the metal. The method of this invention also allows thin steel plate with these features to be reliably manufactured at the industrial level.



WHAT IS CLAIMED IS :

1. A steel sheet providing superior mechanical properties, including precipitates constituting mainly $Ti_4C_2S_2$ and satisfying the following conditions for specific amounts of elements by mass % such that :

Carbon : 0.0010 to 0.010%

Silicon : 1.0% or less

Manganese : 0.1 to 1.0%

Phosphor : 0.1% or less

Sulfur : 0.01 to 0.025%

Nitrogen : 0.01% or less

Titanium : 0.2% or less

Remainder : Fe and unavoidable impurities,

said elements satisfying the conditions of the following formulas:

$$(Ti^*/48)/(C/12 + S/32) = 0.8 \text{ to } 4.0$$

$$Ti^* = Ti - (48/14)N$$

2. A steel sheet of superior mechanical properties according to claim 1, wherein precipitates are comprised internally mainly of $Ti_4C_2S_2$, with a size of 1,000 to 10,000Å and has a count of 5×10^3 pcs/mm² or more.



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3. A steel sheet of superior mechanical properties according to claim 2, wherein the steel sheet is a hot rolled steel sheet and satisfies the following formula.

$$(Ti^*/48)/(C/12 + S/32) = 1.0 \text{ to } 3.0$$

$$Ti^* = Ti - (48/14)N$$

4. A steel sheet of superior mechanical properties according to claim 2, wherein the steel sheet is a cold rolled steel sheet and precipitates mainly comprising $Ti_4C_2S_2$, also include TiS with $Ti_4C_2S_2$ and size of said precipitates is 1,000 to 10,000Å and said precipitates have a count of 1×10^4 to 5×10^5 pcs/mm².

5. A steel sheet of superior mechanical properties according to any of claims 1 through 4, wherein the steel sheet satisfies the following conditions for specific amounts of elements by mass % such that :

Carbon : 0.0010 to 0.008%

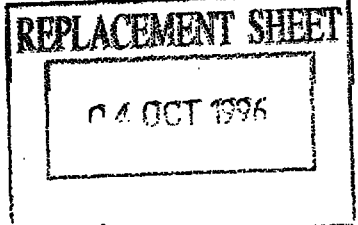
Silicon : 0.25% or less

Manganese : 0.20 to 1.0%

Phosphor : 0.05% or less

Titanium : 0.15% or less

6. A galvanized steel sheet according to claim 1 wherein at least one side of the steel sheet is galvanized with zinc or zinc alloy in amounts of 3 to 40 g/m².



7. A resin coating steel sheet according to claim 5, wherein a plastic coating is formed over said zinc or zinc alloy galvanized sheet to adhere in amounts of 0.1 to 2.5 g/m².

8. A manufacturing method for hot rolled steel sheet providing superior mechanical properties and satisfying the following conditions for specific amounts of elements by mass % such that:

Carbon : 0.0010 to 0.010%

Silicon : 1.0% or less

Manganese : 0.1 to 1.0%

Phosphor : 0.1% or less

Sulfur : 0.01 to 0.025%

Nitrogen : 0.01% or less

Titanium : 0.2% or less,

Remainder : Fe and unavoidable impurities,

said elements satisfying the conditions of the following formulas:

$$(Ti^*/48)/(C/12 + S/32) = 1.0 \text{ to } 3.0$$

$$Ti^* = Ti - (48/14)N$$

said manufacturing method comprising the steps of:



heating said steel within a temperature range of 1,100 to 1,200°C, and completing hot rolling within the temperature range (Ar_3 transformation temp. +80°C) to (Ar_3 transformation temp. -40°C) followed by coiling at a temperature range not more than 700°C to produce precipitates comprised internally mainly of $Ti_4C_2S_2$, with a size of 1,000 to 10,000Å and a count of 5×10^3 pcs/mm² or more.

9. A manufacturing method for cold rolled steel sheet providing superior mechanical properties and satisfying the following conditions for specific amounts of elements by mass % such that :

Carbon : 0.0010 to 0.010%

Silicon : 1.0% or less

Manganese : 0.1 to 1.0%

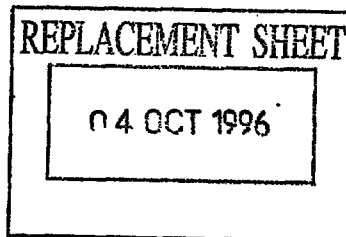
Phosphor : 0.1% or less

Sulfur : 0.01 to 0.025%

Nitrogen : 0.01% or less

Titanium : 0.2% or less,

Remainder : Fe and unavoidable impurities,



said steel satisfying the conditions of the following formulas:

$$(Ti^*/48)/(C/12 + S/32) = 0.8 \text{ to } 4.0$$

$$Ti^* = Ti - (48/14)N$$



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said manufacturing method comprising the steps of:
heating said steel within a temperature range of 1,100 to 1,200°C, and completing hot-rolling within the temperature range (Ar₃ transformation temp. +80°C) to (Ar₃ transformation temp. -40°C) followed by coiling at a temperature range between 600 to 700°C, and after cold rolling of the steel, carrying out annealing to produce precipitates comprised internally mainly of Ti₄C₂S₂ or Ti₄C₂S₂ and TiS, with a size of 1,000 to 10,000Å and a count of 1×10^4 to 5×10^5 pcs/mm².

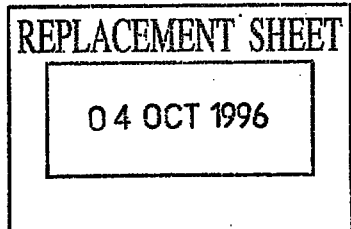
STEEL SHEET HAVING EXCELLENT PROCESSING CHARACTERISTICS,
MANUFACTURING METHOD THEREFOR, AND GALVANIZED STEEL
SHEET AND A RESIN COATING STEEL SHEET
A B S T R A C T

A steel sheet is disclosed, said steel sheet being made of a steel containing specific amounts of carbon, silicon, manganese, phosphorus, sulfur, nitrogen, and titanium, with said steel also satisfying the conditions of the following formulas:

$$(Ti^*/48)/(C/12 + S/32) = 0.8 \text{ to } 4.0$$

$$Ti^* = Ti - (48/14)N$$

of which, a steel sheet and manufacturing method thereof providing said steel sheet having excellent mechanical properties, forming and punch processability characteristics and internally including precipitates constituting mainly $Ti_4C_2S_2$, or $Ti_4C_2S_2$ and TiS . Said steel sheet further, formed with a zinc or galvanized surface and that surface is coated with anti-corrosive, fingerprint-resistant plastic covering.

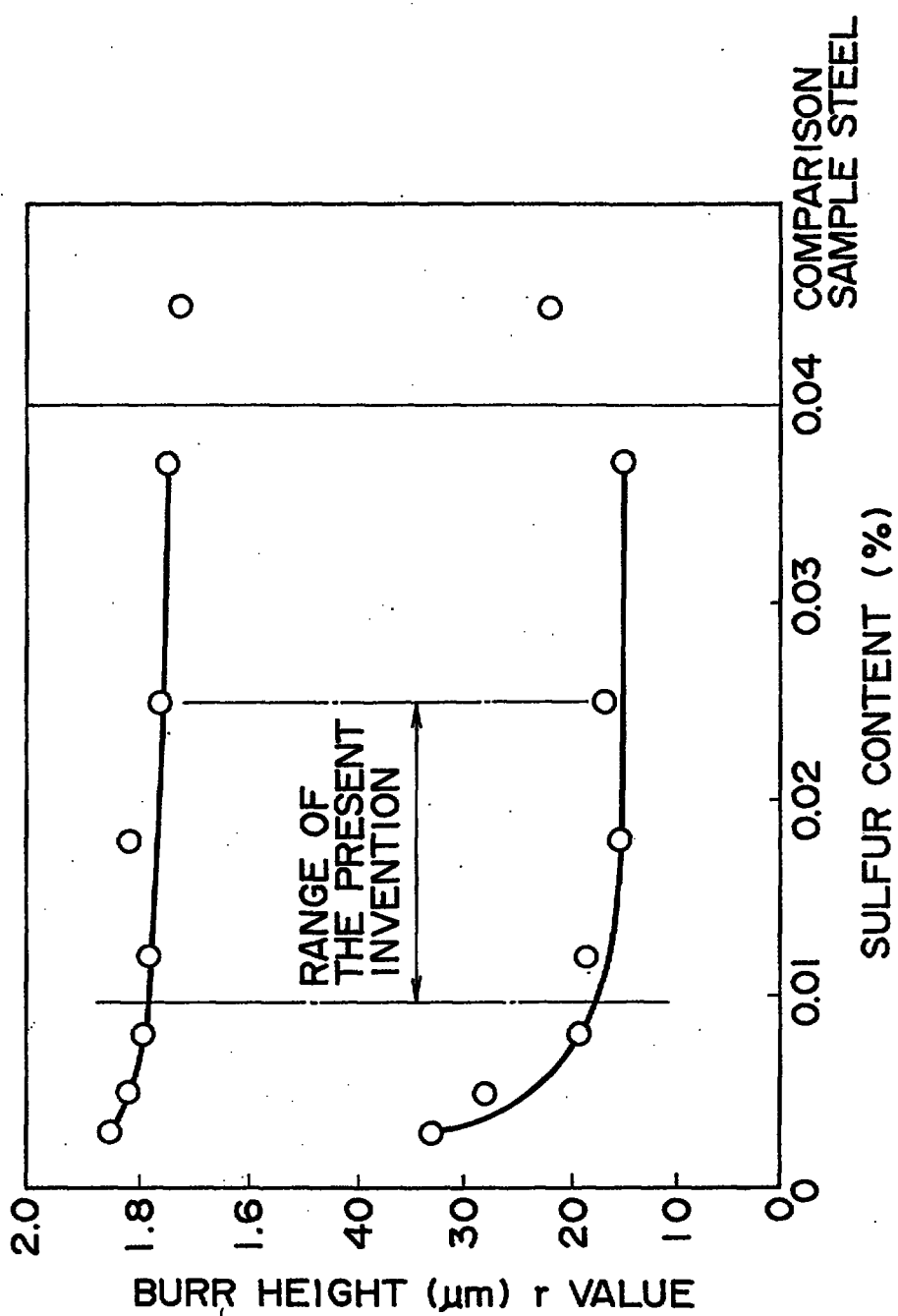


REPLACEMENT SHEET

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FIG. 1



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FIG. 2

