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- (54) **Kiváló mechanikai szilárdságú és alakíthatóságú acéllemez, továbbá gyártási eljárás és alkalmazása**

Az európai szabadalom ellen, megadásának az Európai Szabadalmi Közlönyben való meghirdetésétől számított kilenc hónapon belül, felszólalást lehet benyújtani az Európai Szabadalmi Hivatalnál. (Európai Szabadalmi Egyezmény 99. cikk(1))

A fordítást a szabadalmas az 1995. évi XXXIII. törvény 84/H. §-a szerint nyújtotta be. A fordítás tartalmi helyességét a Szellemi Tulajdon Nemzeti Hivatala nem vizsgálta.

STEEL SHEET HAVING VERY HIGH MECHANICAL PROPERTIES OF STRENGTH AND DUCTILITY, MANUFACTURING METHOD AND USE OF SUCH SHEETS

The present invention covers the manufacturing of steel sheets having very high strength, simultaneously having mechanical strength and deformability allowing cold forming operations. More precisely, the invention relates to steels having a mechanical strength of more than 900 MPa, an elastic limit of more than 700 MPa and uniform elongation of more than 12%. Vehicles, in particular motorised land vehicles (automobiles, combine harvesters, trailers, semi-trailers, etc.) fall within the field of application of these steel sheets. They can also be used as structural parts, reinforcement elements or even for the manufacture of abrasion-resistant parts.

Strong demand for reductions in greenhouse gas emissions, coupled with growing automobile safety requirements and fuel prices have pushed motorised land vehicle manufacturers to make increasing use of improved mechanical strength steels in the bodywork to reduce the thickness of the parts and therefore the weight of the vehicles while maintaining the mechanical strength performances of the structures. From this perspective, steels combining high strength with formability sufficient for shaping without the occurrence of cracks become increasingly important. Thus, over time, several families of steels offering various levels of mechanical strength have been successively offered. These families include DP for Dual Phase steels, TRIP for Transformation Induced Plasticity steels, Multiphase steels or even low density steels (FeAl).

In order to meet this demand for lighter vehicles, it is therefore necessary to have steels that are increasingly strong to compensate for the drop in thickness. However, it is known that in the field of carbon steels, an increase in mechanical strength is generally accompanied by a loss of ductility. In addition, the manufacturers of motorised land vehicles define increasingly complex parts, which require steels with high levels of ductility.

We have read the patent WO2012164579 showing a microstructure composed mainly of bainite for a steel with the following chemical composition C: 0.25 – 0.55, Si: 0.5 – 1.8, Mn: 0.8 – 3.8, Cr: 0.2 – 2.0, Ti: 0.0 – 0.1, Cu: 0.0 – 1.2, V: 0.0 – 0.5, Nb: 0.0 – 0.06, Al: 0.0 – 2.75, N: <0.004 P: < 0.025 S: < 0.025 as well as the process for the manufacture of this hot rolled bainitic steel comprising the steps of cooling the wound sheets until they reach ambient temperature, the bainitic transformation taking place during cooling. The bainitic microstructure within the scope of this patent is obtained by a hot rolled process, which results in a thick, high strength sheet. Cold rolling to reduce the thickness requires very high strength and the hot rolled sheet does not meet the requirement of lightening to meet the requirements of the automobile sector.

On the other hand, patent EP1553202 is known, which exhibits a very high strength steel with high strength to hydrogen embrittlement comprising: 0.06 - 0.6% of C; 0.5 - 3% of Si+Al; 0.5 - 3% of Mn; less than 0.15% of P; less than 0.02% of S wt.-%, the microstructure includes more than 3% of residual austenite, more than 30% of bainitic ferrite, and preferably less than 50% of polygonal ferrite in surface fraction. The steels obtained with this invention exhibit a significant distribution in terms of mechanical property due to the large windows in terms of chemical composition and metallurgical choices, i.e. production parameters.

The purpose of the present invention is to solve the problems mentioned above. It is intended to provide cold rolled steel having mechanical strength of more than 900 MPa, an elastic limit of more than 700 MPa



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combined with uniform elongation of more than 12%. The invention is also mainly concerned with providing steel capable of stable production. The reliability of the production approach is a major element of the invention.

Such that, the manufacturing cost is reduced and the thermomechanical manufacturing approaches are simplified and not very dispersive.

To this end, the purpose of invention is to obtain a cold rolled and annealed steel sheet having mechanical strength of more than or equal to 900 MPa, an elastic limit of more than 700 MPa and uniform elongation of more than or equal to 12% whose composition comprises, the contents being expressed as a percentage of weight (wt.-%): $0.26\% \leq C \leq 0.45\%$, preferably $0.26\% \leq C \leq 0.35\%$, $1.0\% \leq Mn \leq 3.0\%$, preferably $1.4\% \leq Mn \leq 2.6\%$, $1.0\% \leq Si \leq 3.0\%$, preferably $1.4\% \leq Si \leq 1.8\%$, $Al \leq 0.1\%$, $Cr \leq 1.5\%$, preferably $Cr \leq 0.5\%$, $S \leq 0.005\%$, $P \leq 0.020\%$, $Nb \leq 0.1\%$, preferably $Nb \leq 0.05\%$, $Ti \leq 0.02\%$, $V \leq 0.015\%$, $N \leq 0.01\%$, the rest of the composition consisting of iron and unavoidable impurities resulting from the production, with the proviso that $256xC + 47xMn + 150xCr + 2260xNb > 142$, the microstructure consisting of 13 to 25% residual austenite in surface proportions, 13 to 30% of residual martensite and austenite islets, and the balance consisting of ferrite and bainite.

Preferably, the steel according to the invention contains maximum 30% of ferrite.

Preferably, the total elongation of steel according to the invention is greater than 14, or even 15%.

Preferably, it contains a coating of zinc or a zinc alloy, or even a coating of aluminium or an aluminium alloy.

The invention also relates to a method for manufacturing an annealed, cold rolled steel sheet with a strength greater than or equal to 900 MPa, an elastic limit greater than 700 MPa and an elongation greater than or equal to 12% comprising steps according to which:

- a composition steel is provided, then
- said steel is cast in the form of semi-finished product, then
- said semi-finished product is brought to a temperature T_{reht} between 1150°C and 1275°C to obtain a reheated semi-finished product, then
- said reheated semi-finished product is hot rolled, the end of hot rolling temperature T_h being greater than or equal to 850°C to obtain a hot rolled sheet, then
- said hot rolled sheet is wound at temperature T_{wck} ranging between 540 and 590°C to obtain a wound hot rolled sheet, then,
- said hot rolled sheet is cooled till it reaches ambient temperature, then,
- optionally, annealing, considered to be the basis of the wound hot rolled sheet, is carried out such that the sheet is annealed at a temperature of 400°C to 700°C for a period of 5 to 24 hours,
- said wound and annealed hot rolled sheets are unwound and cleaned in order to obtain a hot rolled sheet that can be cold rolled, then
- said hot rolled sheet capable of being cold rolled is cold rolled with a reduction rate between 30 to 80% in order to obtain a cold rolled sheet, then,
- the cold rolled sheet is annealed by reheating it at a speed V_c between 2 to 50°C/s until it reaches a temperature T_{wckng} between 760 to 1100°C, for a period t_{wckng} between 60 to 600 seconds, then,

- said cold rolled sheet is cooled by subjecting it to cooling at a speed between 20 to 1000°C/sec such that the end of cooling temperature T_{CA} lies between 360°C and 440°C, it being understood that:

$$T_{\text{soaking}} < 1.619 (T_{CA} - T1) \text{ where } T1 = -206 C - 43 Mn - 164 Cr - 896 Nb.$$

$$T_{\text{soaking}} > 1.619 (T_{CA} - T2) \text{ where } T2 = 50 C + 4 Mn - 14 Cr + 1364 Nb - 132.$$

With temperatures in °C and the chemical compositions in percentage of weight,

- said cold rolled sheet is maintained within the temperature range of 360 to 440°C for a period t_{CA} between 100 to 2000 seconds.

Preferably, at the end of cooling temperature T_{CA} , said sheet is maintained isothermally between 360 to 440°C for 100 to 2000 seconds.

Preferably, the end of rolling temperature T_R is greater than or equal to 900°C.

Preferably, the annealed sheet is cooled (if it reaches ambient temperature before being coated with zinc or zinc alloy using a suitable process such as electrolytic or physico-chemical deposition.

Optionally, the annealed cold rolled sheet is coated with zinc or zinc alloy by hot-dip galvanising prior to cooling to ambient temperature.

Optionally, the annealed cold rolled sheet can be coated with aluminium or aluminium alloy through a hot-dip aluminizing process before cooling until it reaches ambient temperature.

Optionally, the annealed sheet is cold rolled once again at a cold rolling rate between 0.1 to 3%.

Preferably, said annealed sheet is annealed and coated at a holding temperature T_{base} between 150°C to 190°C for a holding time t_{base} between 10 hours to 48 hours.

Optionally, the sheet can be hot stamped after annealing at the temperature of T_{soaking} prior to cooling at speed V_c .

The steel sheet according to the invention, cold rolled and annealed, or manufactured using a method according to the invention, is used to manufacture parts for motorised land vehicles.

Other characteristics and benefits of the invention will appear in the description given below.

According to the invention, the carbon content lies between 0.26 and 0.45 wt.-%. If the carbon content of the invention is below 0.26 wt.-%, the mechanical strength becomes insufficient and the fraction of residual austenite is still insufficient to attain uniform elongation of more than 12%. Beyond 0.45%, it becomes increasingly difficult to weld as microstructures with low stiffness are formed in the Thermally Affected Zone (TAZ) or in the melting zone in case of resistance welding. According to a preferred embodiment, the carbon content lies between 0.26 and 0.35%. Within this range, the welding capacity is satisfactory, austenite stabilisation is optimised and martensite fraction is within the range targeted by the invention.

Manganese is an element which hardens with a solid substitution solution. It stabilises the austenite and lowers the $Ac3$ transformation temperature. Thus, manganese contributes to an increase in the mechanical strength. According to the invention, a minimum content of 1.0 wt.-% is necessary to obtain the desired mechanical properties. However, beyond 3.0%, its gammagenic characteristic leads to the formation of an excessively marked strip structure, which can impair the shaping properties of the automotive structure part, and

moreover, the coatability will be reduced. Preferably, a 1.4% to 2.6% range of manganese content combines satisfactory mechanical strength without increasing the risk of forming strip structures that are harmful to shaping or increase the hardenability in welded alloys, which would adversely affect the welding capacity of the sheet according to the invention.

The stabilisation of residual austenite is made possible by adding silicon, which considerably slows down the precipitation of carbides during the annealing cycle and, more particularly, during the bainitic transformation. This arises from the fact that the solubility of silicon in cementite is very low and this element increases carbon activity in austenite. Any formation of cementite will therefore be preceded by a step of rejection of the Si at the interface. The enrichment of austenite in carbon thus leads to its stabilisation at ambient temperature on the annealed steel sheet. Subsequently, the application of an external constraint, e.g. shaping, will lead to the transformation of this austenite into martensite. This transformation also improves the resistance to damage. With regard to the properties targeted by the invention, adding more than 3.0% silicon will significantly promote the ferrite while the targeted mechanical strength would not be achieved, and moreover, strongly bonding oxides would be formed, which would lead to surface defects. The minimum content must also be set at 1.0 wt.-% in order to obtain a stabilising effect on the austenite. Preferably, the silicon content will lie between 1.4 and 1.8% in order to optimise the aforementioned effects.

The content of chromium must be limited to 1.5%, wherein this element allows control of the formation of proeutectoid ferrite on cooling at the time of annealing based on said holding temperature T_{soaking} , wherein this ferrite, in high quantity, reduces the mechanical strength required for the sheet according to the invention. Furthermore, this element allows hardening and refining of the bainitic microstructure. Preferably, the content of chromium will be less than 0.5% for reasons of cost and to avoid excessive hardening.

Nickel and copper have effects substantially similar to those of manganese. These two elements will be in residual amounts.

Aluminium content is limited to 0.1 wt.-%. This element is a powerful alphagene, which favours the formation of ferrite. High aluminium content would increase the A_{c3} point and thus make the industrial process expensive in terms of energy supply for annealing. It is also considered that high aluminium contents increase the erosion of the refractories and the risk of plugging the nozzles during the casting of the steel upstream of the rolling. Additionally, aluminium segregates negatively and, it can lead to macro-segregations. In excessive quantities, aluminium reduces hot ductility and increases the likelihood of continuous casting defects. Without a thorough check of the casting conditions, micro and macro segregation type defects ultimately lead to central segregation on the annealed steel sheet. This central band will be harder than its adjacent matrix and will impair the formability of the material.

For sulphur, beyond a content of 0.005%, ductility is reduced due to the excessive presence of sulphides such as MnS, known as manganese sulphides, which reduce formability.

Phosphorus is an element which hardens in solid solution but greatly reduces spot weldability and hot ductility, particularly due to its ability to segregate at grain boundaries or its tendency to co-segregate with manganese. For these reasons, its content should be limited to 0.020% in order to obtain good spot weldability.

Niobium is a micro-alloy element, which forms precipitates that harden with carbon and/or nitrogen. These precipitates, already present during the hot rolling operation, delay recrystallisation during annealing and

thus refine the microstructure, which makes it possible to contribute to the hardening of the material. It also makes it possible to improve the elongation properties of the product by allowing annealing at high temperatures without lowering the elongation performance by a structural refining effect. The niobium content must, however, be limited to 0.1% to avoid excessive hot rolling and for economic reasons. Preferably, the niobium content will be less than 0.05% in order to avoid excessive hardening of the cold sheet and for reasons of cost. In another embodiment, it is preferred that the niobium content is greater than or equal to 0.001%, which makes it possible to have a hardening of the ferrite, when it is present and when such hardening is desired.

The other micro-alloy elements such as titanium and vanadium are limited to the maximum contents of 0.02% and 0.015% respectively, because these elements possess the same advantages as niobium, but they have the specific characteristic of reducing the ductility of the product. This limitation is also economical.

Nitrogen is limited to 0.01% in order to avoid aging phenomena of the material and to minimise precipitation of aluminium nitrides (AlN) during solidification and thus to weaken the semi-finished product.

The rest of the composition consists of iron and unavoidable impurities resulting from the preparation.

According to the invention, the microstructure of the steel must contain, in surface proportions, 13 to 25% austenite. If the residual austenite content is less than 13%, uniform elongation will be less than 12%. If it is more than 25%, the residual austenite will be unstable as it is not rich enough in carbon, while the ductility of steel will be reduced. The elasticity limit will be less than 700MPa.

Furthermore, the steel according to the invention must contain 13 to 30% of MA islets, i.e. residual austenite and martensite islets, i.e. the latter may be fresh or returned indifferently. If the content of MA islets is less than 13%, the mechanical strength of 900 MPa will not be reached, while if it is more than 30%, uniform elongation will be less than 12%.

The balance of the microstructure consists of bainite and optionally of ferrite. Preferably, ferrite, when present, is of polygonal type.

The steel sheet according to the invention may be manufactured using any suitable method. For example, the method according to the invention may be used, which may include the steps to be described.

A steel of the composition according to the invention is first supplied. Then, a semi-finished product is cast from this steel. This casting may be carried out in ingots or continuously in the form of slabs.

The cast semi-finished products can then be brought to a temperature T_{reheat} of more than 1150°C to obtain a reheated semi-finished product in order to attain at all points a temperature favourable to the high deformations that the steel will undergo during rolling. This temperature range makes it possible to be in the austenitic region. However, if the temperature T_{reheat} is greater than 1275°C, the austenitic grains will grow undesirably and will lead to a coarser final structure, while the risks of surface defects related to the presence of liquid oxide are increased. Obviously, it is also possible to hot roll immediately after casting without reheating the slab.

Thus, the semi-finished product is hot rolled in a temperature range where the steel structure is totally austenitic: if the end of rolling temperature T_R is less than 850°C, the rolling efforts are very high, which could lead to high energy consumption. Preferably, an end of rolling temperature of more than 900°C should be respected.

The hot rolled product is then wound at a temperature T_{hot} between 540 to 590°C. This temperature range makes it possible to obtain ferritic, bainitic or pearlitic transformations during the quasi-isothermal maintenance associated with the winding followed by slow cooling in order to minimise the fraction of martensite after cooling. A cooling temperature of more than 590°C leads to the formation of undesired surface oxides. When the winding temperature is too low, below 540°C, the hardness of the product after cooling is increased, which increases the efforts required during the subsequent cold rolling.

Then, if necessary, the hot rolled product is cleaned according to a process known per se.

Optionally, the hot rolled sheet wound between T_{RD1} and T_{RD2} with $T_{\text{RD1}} \sim 400^\circ\text{C}$ and $T_{\text{RD2}} \sim 700^\circ\text{C}$ is intermediately annealed for 5 to 24 hours.

This thermal treatment makes it possible to have a mechanical strength of less than 1000 MPa at all points of the hot rolled sheet, thus reducing the difference in hardness between the centre of the sheet and the edges. This significantly facilitates the subsequent step of cold rolling by softening of the formed structure.

Cold rolling is then carried out with a reduction rate preferably between 30 to 80%.

The cold rolled product is then heated, preferably within a continuous annealing installation, with an average heating speed V_c between 2 to 50°C per second. In relation with the annealing temperature T_{soaking} given below, this heating speed range makes it possible to obtain the re-crystallisation and appropriate refining of the structure. Below 2°C per second, risks of surface decarbonisation are avoided. Above 50°C per second, presence of traces of non-recrystallisation and insoluble carbons during maintenance, which would have reduced the fraction of residual austenite, are avoided.

Heating is carried out until an annealing temperature T_{soaking} between 760°C to 1100°C is reached. T_{soaking} of less than 760°C promotes the presence of non-recrystallised phases which are damaging for elongation. Inversely, if T_{soaking} is more than 1100°C, the sizes of the austenitic grains increase significantly, which is damaging for refining the final microstructure and therefore for the levels of elasticity limit.

A holding time between 60 to 600 seconds at temperature t_{soaking} allows dissolution of previously formed carbons, and particularly sufficient transformation into austenite. Below 60 secs, the carbons are insufficiently dissolved. On the other hand, a holding time of more than 600 secs is not easily compatible with the productivity requirements of the continuous annealing installations, particularly the winding speed. Thus, the holding time t_{soaking} is between 60 and 600 secs.

At the end of the annealing, the sheet is cooled till it reaches a temperature T_{OA} of $T_{\text{OA1}} = 360^\circ\text{C}$ to $T_{\text{OA2}} = 440^\circ\text{C}$, while the cooling speed V_{ref} is fast enough to avoid formation of perlite. For this purpose, this cooling speed lies between 20°C and 1000°C per second. Beyond 1000°C per second, it becomes difficult to precisely attain said temperature T_{OA} . Below 360°C, the fraction of bainite is too large and the fraction of residual austenite is insufficient and its stability is therefore too high. Thus, the elongations are insufficient, i.e. below 12% for uniform elongation. Above 440°C, the fraction of bainite is too small to allow an adequate austenite fraction to be stabilised but favours the damaging presence of a very large fraction of martensite. The elasticity limits or elongations are therefore insufficient.

The holding time t_{OA} within the temperature range T_{OA1} (°C) to T_{OA2} (°C) must be more than 100 seconds to allow bainitic transformation and the stabilisation of austenite by adding carbon to said austenite. Also,

it must be less than 2000 secs to avoid carbon precipitation, which will result in reducing the fraction of residual austenite and therefore impairing the ductility of the product.

The combination of the annealing temperature T_{soaking} and holding the temperature at T_{OA} is as defined by the following relations (1) and (2):

Relation 1:

$$T_{\text{soaking}} < 1.619 (T_{\text{OA}} - T_1) \text{ where } T_1 = -206 \text{ C} - 43 \text{ Mn} - 164 \text{ Cr} - 896 \text{ Nb}$$

Relation 2:

$$T_{\text{soaking}} > 1.619 (T_{\text{OA}} - T_2) \text{ where } T_2 = 50 \text{ C} + 4 \text{ Mn} - 14 \text{ Cr} + 1364 \text{ Nb} - 132$$

with temperatures in °C and the chemical compositions in percentage of weight. Preferably, this holding is carried out isothermally.

Respecting these relations between the chemical composition and the annealing temperatures T_{soaking} and the holding temperatures T_{OA} makes it possible to stably have a strength of more than 900 MPa, an elastic limit or more than 700 MPa and finally uniform elongation of more than 12%. This is an essential point of the invention as it allows the metallurgical production approach to be reliable in order to obtain a sheet which does not exhibit different mechanical responses depending on the dispersion of the production process within the temperature ranges and within the ranges of the chemical composition elements of the invention.

Another alternative would be to deposit Zn or Zn alloy (more than 50% of Zn wt.-%) by coating using the hot dip method before cooling to ambient temperature. Preferably, the bare annealed sheet can also be coated with Zinc or Zinc alloy through a known electrolytic or physico-chemical process. An aluminium or aluminium alloy based coating (more than 50% of Al wt.-%) can also be deposited by hot dipping.

Then, a base post-annealing heat treatment is preferably carried out on the cold rolled and annealed sheet and coated, at a holding temperature T_{base} between 150°C to 190°C for a holding time t_{base} between 10 hours to 48 hours in order to improve the elasticity and pliability limit. This treatment will be called: basic post-annealing.

Now, this invention will be illustrated based on the following examples provided as a rough guide.

Examples

The composition of the steels is provided in the table below, expressed in wt.-%. According to the invention, table 1 indicates the chemical composition of the steel that has been used for manufacturing the sheets.

Steel	C	Mn	Si	Al	Cr	Mo	Cu	Ni	V	Nb	S	P	B	Ti	N
A	0.24	1.51	1.48	0.002	0.007	0.002	0.007	0.004	0.002	0.002	0.0015	0.0135	0.0004	0.001	0.004
B	0.29	1.50	1.48	0.002	0.007	0.002	0.007	0.004	0.002	0.002	0.0015	0.0134	0.0004	0.001	0.005
C	0.29	1.51	1.48	0.002	0.007	0.002	0.007	0.004	0.002	0.012	0.0016	0.0140	0.0004	0.001	0.006
D	0.27	2.05	1.44	0.002	0.007	0.002	0.007	0.004	0.002	0.030	0.0008	0.0133	0.0004	0.001	0.006
E	0.31	1.48	1.49	0.003	0.003	0.002	0.002	0.002	0.002	0.001	0.0030	0.0160	0.0004	0.001	0.000
F	0.31	2.46	1.52	0.003	0.000	0.012	0.001	0.001	0.002	0.002	0.0030	0.0020	0.0004	0.001	0.001
G	0.31	2.46	1.49	0.003	0.014	0.002	0.005	0.005	0.002	0.002	0.002	0.004	0.0005	0.0008	0.004

Table 1: Chemical compositions (wt.-%).

Sheets corresponding to the compositions given above were produced according to the manufacturing conditions specified in table 2.

Based on these compositions, some steels have been subjected to different annealing conditions. The conditions before hot rolling are identical to heating between 1230°C and 1275°C, and end of rolling temperature between 930°C to 990°C and winding between 550°C and 580°C. All the hot rolled products are then cleaned and then, depending on the steel, they are directly cold rolled or annealed prior to the cold rolling with a reduction rate between 60 to 70%.

Table 2 also indicates the manufacturing conditions of the sheets annealed after cold rolling with the following references:

- Heating temperatures: T_{cch}
- End of rolling temperature: T_{f}
- Winding temperature: T_{BCB}
- Basic annealing temperature: T_{BA}
- Holding time at T_{BA} : t_{BA}
- Reduction rate at the time of cold rolling
- Heating speed: V_{c}
- Holding temperature: T_{soaking}
- Holding time at T_{soaking} : t_{soaking}
- Cooling speed: V_{cc}
- End of cooling temperature T_{CA}
- Time for holding at temperature T_{CA} : t_{CA}
- Temperatures calculated with relations 1 and 2

Series	ID	T_{heat} (°C)	T_{in} (°C)	T_{top} (°C)	T_{top} (°C)	t_{top} (s)	Reduction (%)	V_{c} (°C/s)	T_{cooling} (°C)	V_{ref} (°C/s)	t_{cooling} (s)	T_{ref} (°C)	t_{ref} (s)	$T1$ (°C)	$T2$ (°C)	Relation 1	Relation 2
A	A 1	1250	967	576	550	6	67	5	830	95	180	550	1000	-115	-114	752	751
A	A 2	1250	967	576	550	6	67	5	830	95	180	400	500	-115	-114	833	832
A	A 3	1250	967	576	550	6	67	5	830	95	180	425	500	-115	-114	874	872
A	A 4	1250	967	576	550	6	67	5	900	95	180	350	1000	-115	-114	752	751
A	A 5	1250	967	576	550	6	67	5	900	95	180	400	500	-115	-114	832	832
A	A 6	1250	967	576	550	6	67	5	900	95	180	425	500	-115	-114	874	872
A	A 7	1250	967	576	650	6	67	5	830	95	180	400	500	-115	-114	833	832
A	A 8	1250	967	576	650	6	67	5	900	95	180	400	500	-115	-114	833	832
B	B 1	1245	939	564	550	6	67	5	790	95	70	350	1000	-125	-111	769	747
B	B 2	1245	939	564	550	6	67	5	790	95	70	400	500	-125	-111	820	822
B	B 3	1245	939	564	550	6	67	5	790	95	70	425	500	-125	-111	820	868
B	B 4	1245	939	564	550	6	67	5	790	95	70	450	500	-125	-111	931	902
B	B 5	1245	939	564	550	6	67	5	830	95	180	350	1000	-125	-111	769	747
B	B 6	1245	939	564	550	6	67	5	830	95	180	400	500	-125	-111	850	828
B	B 7	1245	939	564	550	6	67	5	830	95	180	425	500	-125	-111	890	868
B	B 8	1245	939	564	550	6	67	5	830	95	180	450	500	-125	-111	931	902
B	B 9	1245	939	564	550	6	67	5	900	95	180	350	1000	-125	-111	769	747
B	B 10	1245	939	564	550	6	67	5	900	95	180	400	500	-125	-111	850	828
B	B 11	1245	939	564	550	6	67	5	900	95	180	425	500	-125	-111	890	868
B	B 12	1245	939	564	550	6	67	5	900	95	180	450	500	-125	-111	921	902
C	C 1	1248	955	570	550	6	67	5	790	95	70	350	1000	-136	-95	787	720
C	C 2	1248	955	570	550	6	67	5	790	95	70	400	500	-136	-95	868	801
C	C 3	1248	955	570	550	6	67	5	790	95	70	425	500	-136	-95	908	842
C	C 4	1248	955	570	550	6	67	5	790	95	70	450	500	-136	-95	948	882
C	C 5	1248	955	570	550	6	67	5	830	95	180	350	1000	-136	-95	787	720
C	C 6	1248	955	570	550	6	67	5	830	95	180	400	500	-136	-95	868	801
C	C 7	1248	955	570	550	6	67	5	830	95	180	425	500	-136	-95	908	842
C	C 8	1248	955	570	550	6	67	5	830	95	180	450	500	-136	-95	948	882
C	C 9	1248	955	570	550	6	67	5	900	95	180	350	1000	-136	-95	787	720

Table 2: Conditions for annealing of samples and references

	ID	T_{soak} (°C)	T_{N} (°C)	T_{soak} (°C)	T_{N} (°C)	t_{so} (s)	Reduction (%)	V_c (°C/s)	T_{cooling} (°C)	V_{ref} (°C/s)	t_{cooling} (s)	T_{ox} (°C)	t_{ox} (s)	T1 (°C)	T2 (°C)	Relation 1	Relation 2
C	C 10	1248	955	570	550	6	67	5	900	95	180	400	500	-136	-85	882	801
C	C 11	1248	955	570	550	6	67	5	900	95	180	425	500	-136	-85	908	842
C	C 12	1248	955	570	550	6	67	5	900	95	180	450	500	-136	-85	948	882
C	C 13	1248	955	570	650	6	67	5	780	95	70	400	500	-136	-85	868	801
C	C 14	1248	955	570	650	6	67	5	830	95	180	400	500	-136	-85	868	801
C	C 15	1248	955	570	650	6	67	5	900	95	180	400	500	-136	-85	868	801
D	D 1	1254	983	562	550	6	67	5	770	95	70	350	1000	-171	-69	844	679
D	D 2	1254	983	562	550	6	67	5	770	95	70	400	500	-171	-69	925	780
D	D 3	1254	983	562	550	6	67	5	770	95	70	425	500	-171	-69	866	800
D	D 4	1254	983	562	550	6	67	5	770	95	70	450	500	-171	-69	1006	841
D	D 5	1254	983	562	550	6	67	5	830	95	180	350	1000	-171	-69	844	679
D	D 6	1254	983	562	550	6	67	5	830	95	180	400	500	-171	-69	925	780
D	D 7	1254	983	562	550	6	67	5	830	95	180	425	500	-171	-69	866	800
D	D 8	1254	983	562	550	6	67	5	830	95	180	450	500	-171	-69	1006	841
D	D 9	1254	983	562	550	6	67	5	900	95	180	350	1000	-171	-69	844	679
D	D 10	1254	983	562	550	6	67	5	900	95	180	400	500	-171	-69	925	780
D	D 11	1254	983	562	550	6	67	5	900	95	180	425	500	-171	-69	866	800
D	D 12	1254	983	562	550	6	67	5	900	95	180	450	500	-171	-69	1006	841
D	D 13	1254	983	562	650	6	67	5	830	95	180	400	500	-171	-69	925	780
D	D 14	1254	983	562	650	6	67	5	900	95	180	400	500	-171	-69	925	780
B	B 1	1266	932	538	N.R.	N.R.	62	5	880	95	180	425	500	-128	-110	895	865
F	F 1	1234	946	563	N.R.	N.R.	63	5	900	95	90	300	1800	-184	-105	783	650
F	F 2	1234	946	563	N.R.	N.R.	63	5	900	95	90	400	1800	-184	-105	945	813
G	G 1	1270	951	553	N.R.	N.R.	64	5	860	95	180	325	1200	-170	-107	801	699
G	G 2	1270	951	553	N.R.	N.R.	64	5	860	95	180	350	1200	-170	-107	842	739
G	G 3	1270	951	553	N.R.	N.R.	64	5	860	95	180	375	1200	-170	-107	882	780
G	G 4	1270	951	553	N.R.	N.R.	64	5	860	95	180	400	1200	-170	-107	923	820
G	G 5	1270	951	553	N.R.	N.R.	64	5	860	95	180	425	1200	-170	-107	963	861
G	G 6	1270	951	553	N.R.	N.R.	64	5	860	95	180	450	1200	-170	-107	1004	901

Table 2 (continued): Conditions for annealing of the samples and references

References A1 to A8, B1 to B5, B7 to B12, C1 to C5, C7 to C10, C12, C13, C15, D1, D3 to D5, D8, D9, D12, F1, G1, G2, G5 and G6 of table 2 describe the steel sheets manufactured according to conditions that do not comply with the invention from steels whose compositions are provided in table 1. The parameters that do not comply with the invention are underlined.

It should be noted that the two references D1 and D5 are not in accordance with the invention because the end of cooling temperature T_{ox} is less than 360°C, which favours a large quantity of bainitic ferrite and a small amount of residual austenite, thus limiting the ductility of the sheet.

It should also be noted that the two references C12 and D12 are not in accordance with the invention as the end of cooling temperature T_{QA} is more than 440°C, which favours a small amount of bainite ferrite and unstable residual austenite, thus limiting the ductility and the elastic limit of the sheet.

It should also be noted that references A5, A6, A8, B10, B11, C10 and C15 are not in accordance with the invention as the temperature $T_{soaking}$ is less than the temperature calculated by relation 1, depending on their respective composition.

It should also be noted that references A2, A3, A7, B2, B3, B7, C2, C3, C7, C13, D3 and G5 are not in accordance with the invention as the temperature $T_{soaking}$ is more than the temperature calculated by relation 2, also depending on their respective composition.

Finally, it should be noted that references A1, A4, B1, B4, B5, B7, B9, B12, C1, C4, C5, C8, C9, D4, D8, D9, F1, G1, G2 and G6 are not in accordance with the invention as the end of cooling temperature T_{QA} is outside the range 360°C - 440°C and that the holding temperature $T_{soaking}$ is either less than the temperature calculated with relation 1, or more than the temperature calculated with relation 2, leading to the adverse consequences mentioned above.

Samples B6, C6, C11, C14, D2, D6, D7, D10, D11, D13, D14, E1, F2, G3 and G4 are the ones that are in accordance with the invention.

Then, the mechanical properties are measured by using an ISO 12.5x50 type test specimen. The uniaxial tractions that make it possible to obtain these mechanical properties are applied in the direction parallel to that of cold rolling.

The mechanical properties of traction obtained were recorded in table 3 below with the following abbreviations:

- Elasticity limit: Re
- Mechanical strength: Rm
- Uniform elongation: A1. Unif.
- Total elongation: A1. Total

ID	Re (GPa)	Im (GPa)	At. Load (%)	At. Total (%)	Re/Im	Re:Im	Re:Im	Re:Im	Re:Im
A	A.1	832	909	9.3	12.7	0.68			6129
A	A.2	381	862	18.4	21.6	0.67			9328
A	A.3	230	812	16.5	18.2	0.62			8745
A	A.4	1076	1286	2.4	3.7	0.94			2382
A	A.5	843	1025	9.4	14.5	0.82			7926
A	A.6	162	668	10.0	12.0	0.79			7626
A	A.7	366	822	21.0	26.2	0.67			11949
A	A.8	248	1021	7.1	12.5	0.82			6369
B	B.1	224	932	20.2	35.2	0.64			11929
B	B.2	222	882	22.7	28.7	0.66			13089
B	B.3	381	604	21.5	26.1	0.63			12492
B	B.4	222	966	15.6	18.6	0.56			8408
B	B.5	225	1115	6.9	11.4	0.75			2762
B	B.6	714	966	12.2	17.5	0.74			9129
B	B.7	832	924	16.2	19.1	0.69			10630
B	B.8	224	974	12.9	16.9	0.59			7405
B	B.9	1121	1303	2.7	3.7	0.86			3162
B	B.10	878	1869	2.4	10.0	0.82			6497
B	B.11	782	1012	10.9	15.3	0.77			8337
B	B.12	678	1001	8.5	10.5	0.68			5763
C	C.1	222	902	13.9	18.4	0.64			8026
C	C.3	222	882	24.5	29.2	0.65			14161
C	C.5	252	928	22.5	27.6	0.61			12689
C	C.4	224	928	13.9	15.6	0.56			7284
C	C.5	725	1016	8.2	12.4	0.71			6863
C	C.6	622	926	19.4	23.0	0.68			12286
C	C.7	648	933	18.8	24.2	0.67			12031
C	C.8	242	939	13.7	17.3	0.57			7521
C	C.9	1133	1245	2.2	3.4	0.86			2630

ID	Re (GPa)	Im (GPa)	At. Load (%)	At. Total (%)	Re/Im	Re:Im	Re:Im	Re:Im	Re:Im
C	C.10	829	1064	8.1	12.8	0.54			8299
C	C.11	803	1024	12.1	15.1	0.78			9680
C	C.12	634	1001	8.8	13.9	0.69			6831
C	C.13	382	854	20.0	22.6	0.58			11660
C	C.14	711	951	13.7	16.9	0.76			9741
C	C.15	828	1092	2.2	10.1	0.82			6761
D	D.1	674	1129	13.2	16.9	0.80			10245
D	D.2	708	1129	15.2	15.6	0.63			10762
D	D.3	548	1211	13.1	13.1	0.45			7179
D	D.4	482	1369	3.2	4.8	0.39			2892
D	D.5	925	1221	4.8	7.3	0.77			4422
D	D.6	739	1097	14.5	17.9	0.60			11306
D	D.7	749	1120	14.0	14.2	0.58			10458
D	D.8	519	1212	12.0	14.1	0.43			6228
D	D.9	1115	1266	5.1	7.6	0.80			2687
D	D.10	863	1168	12.1	15.4	0.74			10442
D	D.11	735	1139	12.8	16.3	0.66			9864
D	D.12	507	1192	8.6	9.1	0.43			4512
D	D.13	810	1078	15.4	19.3	0.73			13474
D	D.14	839	1137	12.9	17.0	0.74			10325
E	E.1	739	1044	13.4	20.9	0.74			10789
F	F.1	1427	1712	2.2	3.4	0.74			2780
F	F.2	829	1225	12.1	16.1	0.74			10639
G	G.1	1122	1365	5.5	2.6	0.74			8142
G	G.2	1012	1261	8.2	12.6	0.74			8914
G	G.3	843	1284	12.1	14.8	0.74			10225
G	G.4	721	1289	12.1	14.5	0.74			8482
G	G.5	661	1384	10.4	11.2	0.74			8089
G	G.6	780	1317	6.2	6.2	0.74			4826

Table 3: Mechanical properties of the references and the inventions

References A1 to A8, B1 to B5, B7 to B12, C1 to C5, C7 to C10, C12, C13, C15, D1, D3 to D5, D8, D9, D12, F1, G1, G2, G5 and G6 of table 3 describe the steel sheets manufactured according to the conditions described in table 2 from steels whose compositions are specified in table 1. The mechanical properties not in accordance with the invention are underlined.

Samples B6, C6, C11, C14, D2, D6, D7, D10, D11, D13, D14, E1, F2, G3 and G4 are the ones that are in accordance with the invention.

It should be noted that references B1, B3, B4, B7, B8, C1, C3, C4, C7, C8, D1, D3 and D8 are not in accordance with the invention, as the elasticity limit R_e is less than 700MPa, which either corresponds to a very small amount of bainitic ferrite due to an end of cooling temperature T_{CA} of more than 440°C or a very large amount of polygonal ferrite due to a holding temperature $T_{soaking}$ of less than that calculated with relation 1.

It should also be noted that the two references A4 to A6, A8, B2, B11, C5, C9, C10, C15, D5, D9, F1, G1, G2 and G6 are not in accordance with the invention as uniform elongation is less than 12%, which either corresponds to a very small amount of polygonal ferrite due to a holding temperature $T_{soaking}$ of more than that calculated with relation 2, or a very small amount of residual austenite due to an end of cooling temperature T_{CA} of less than 360°C.

It should also be noted that references A1, B5, B6, B12 and C12 are not in accordance with the invention as the elasticity limit R_2 and uniform elongation are less than 700 MPa and 12% respectively, which corresponds to a very large amount of MA islets due to an end of cooling temperature of more than 440°C.

Finally, it should be noted that references A2, A3, A7, B2, C2, C13, D4, D12 and G5 are not in accordance with the invention as the elasticity limit R_e and mechanical strength R_m are less than 700 MPa and 900 MPa respectively, which corresponds to a very large amount of polygonal ferrite and consequently a holding temperature $T_{soaking}$ of less than the temperature calculated with relation 1, and a very small amount of MA islets due to a very low end of cooling temperature T_{CA} .

The invention makes it possible to provide a steel sheet capable of receiving a coating of a Zinc or Zn alloy coating, in particular by the regular electro-galvanising process.

The invention also makes it possible to provide a steel sheet capable of receiving a Zinc or Zn alloy coating, in particular by a process of hot-dipping in a liquid Zn bath followed or not by an alloy thermal treatment.

Finally, it makes it possible to provide steel having good weldability by means of the usual joining methods such as, for example, but not limited to, spot welding.

According to the invention, the steel sheets will be advantageously used for manufacturing parts of structures, reinforcement, safety, anti-abrasive elements or elements of transmission disks for use in motorised land vehicles.

**Kiváló mechanikai szilárdságú és alakíthatóságú acéllemez,
továbbá gyártási eljárása és alkalmazása**

SZABADALMI IGÉNYPONTOK

1. Hidegen hengerelt és lágyított acéllemez, amelynek mechanikai szilárdsága nagyobb vagy egyenlő, mint 900MPa, továbbá folyáshatára nagyobb, mint 700 MPa és egyenletes nyúlása nagyobb vagy egyenlő, mint 12%, és amelynek összetétele tömegszázalékban kifejezve a következő:

$$0,26\% \leq C \leq 0,45\%$$

$$1,0\% \leq Mn \leq 3,0\%$$

$$1,0\% \leq Si \leq 3,0\%$$

$$Al \leq 0,1 \%$$

$$Cr \leq 1,5\%$$

$$S \leq 0,005\%$$

$$P \leq 0,020\%$$

$$Nb \leq 0,1\%$$

$$Ti \leq 0,02\%$$

$$V \leq 0,015\%$$

$$N \leq 0,01\%$$

a maradék vas és elkerülhetetlen szennyeződések, amelyek a gyártás során kerülnek az acélba, azzal a feltétellel, hogy $256xC + 47xMn + 150xCr + 2260xNb > 142$, és a mikrokristályos szerkezet csiszolat felületi arányában 13 és 25% közötti maradék ausztenitet, 13 és 30% közötti arányban maradék martenzitet és ausztenit szigeteket tartalmaz, ahol a további szövetelem bénit és adott esetben ferrit.

2. Az 1. igénypont szerinti acéllemez, amelynek tömegszázalékban kifejezett összetételében

$$0,26\% \leq C \leq 0,35\%$$

3. Az 1 vagy 2 igénypontok bármelyike szerinti acéllemez, amelynek tömegszázalékban kifejezett összetételében

$$1,4\% \leq Mn \leq 2,6\%$$

4. Az 1-3. igénypontok bármelyike szerinti acéllemez, amelynek tömegszázalékban kifejezett összetételében

$$1,4\% \leq Si \leq 1,8\%$$

5. Az 1-4. igénypontok bármelyike szerinti acéllemez, amelynek tömegszázalékban kifejezett összetétel-



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ében

$$\text{Cr} \leq 0,5\%.$$

6. Az 1-5. igénypontok bármelyike szerinti acéllemez, amelynek összetételében tömegszázalékban kifejezve

$$\text{Nb} \leq 0,05\%.$$

7. Az 1-6. igénypontok bármelyike szerinti acéllemez, amelynek mikro-kristályszerkezete legfeljebb 30% ferritet tartalmaz.
8. Az 1-7. igénypontok bármelyike szerinti acéllemez, amelynek teljes nyúlása több mint 14%.
9. Az 1-8. igénypontok bármelyike szerinti acéllemez, amely cink vagy cinkdioxid bevonattal van ellátva.
10. Gyártási eljárás hidegen hengerelt és lágyított acéllemez előállítására, amelynek mechanikai szilárdsága nagyobb vagy egyenlő, mint 900MPa, továbbá folyáshatára nagyobb, mint 700 MPa és nyúlása nagyobb vagy egyenlő, mint 12%, ahol az eljárás során a következő lépéseket hajtjuk végre:
- az 1-6. igénypontok bármelyike szerinti összetételű acélt alkalmazunk,
 - az említett acélt, félkész terméket előállítva, öntjük, majd ezt követően
 - a félkész terméket 1150 °C és 1250 °C közötti T_{red} hőmérsékletre hevítjük annak érdekében, hogy újraizitott félkész terméket kapjunk, majd ezt követően
 - az újraizitott félkész terméket melegen hengereljük, és a meleg hengerelés végén a hőmérsékletet T_f nagyobb vagy egyenlő, mint 850 °C annak érdekében, hogy melegen hengerelt lemezt kapjunk, majd ezt követően
 - az említett melegen hengerelt lemezt 540 és 590 °C közötti T_{rob} hőmérsékleten feltekerceseljük annak érdekében, hogy feltekerceselt melegen hengerelt lemezt kapjunk, majd ezt követően
 - a feltekerceselt melegen hengerelt lemezt lehűtjük mindaddig, amíg szobahőmérsékletű lesz, majd ezt követően
 - adott esetben lágyítjuk a melegen hengerelt lemeztakercset úgy, hogy a lemezt 400 °C és 700 °C közötti hőmérsékleten 5-24 óráig hőntartjuk,
 - a melegen hengerelt lemeztakercset lecsévéljük és megtisztítjuk annak érdekében, hogy melegen hengerelt lemezt kapjunk, amely hidegen hengerelhető, majd ezt követően
 - a hidegen hengerelhető, melegen hengerelt lemezt hidegen hengereljük 30-tól 80% közötti fogyással annak érdekében, hogy a hidegen hengerelt lemezt állítsunk elő, majd ezt követően
 - a hidegen hengerelt lemezt 2-50 °C/másodperc V_c hevítési sebességű újrahevítéssel lágyítjuk mindaddig, amíg 760- 1110 °C közötti T_{soaking} hőmérsékletet elérjük, amelyen 60 és 600 másodperc közötti T_{soaking} idővel hőntartjuk, majd ezt követően

- az említett hidegen hengerelt lemezt 200 és 1000 °C/másodperces hűtési sebességgel lehűtjük úgy, hogy a hűtés véghőmérséklete T_{DA} adott esetben 360 °C és 440 °C között van, figyelembe véve, hogy:

$$T_{\text{soaking}} < 1,619 (T_{DA} - T1) \text{ ahol } T1 = -206 \text{ C} - 43 \text{ Mn} - 164 \text{ Cr} - 896 \text{ Nb.}$$

$$T_{\text{soaking}} > 1,619 (T_{DA} - T2) \text{ ahol } T2 = 50 \text{ C} + 4 \text{ Mn} - 14 \text{ Cr} + 1364 \text{ Nb} - 132.$$

ahol a hőmérséklet mértékegysége °C és a kémiai összetételi tömegszázalékban adjuk meg,

és ahol a hidegen hengerelt lemezt 360 és 440 °C közötti hőmérsékleten 100 és 2000 másodperc t_{DA} ideig hűntartjuk.

11. A 10. igénypont szerinti gyártási eljárás, amelynek során az említett lemezt 100 és 2000 másodperc közötti ideig, 360 és 440 °C közötti hőmérsékleten izotermásan hűntartjuk a T_{DA} lehűtési hőmérséklet végén.
12. A 10-11. igénypontok bármelyike szerinti gyártási eljárás, ahol a T_R hőmérséklet nagyobb vagy egyenlő, mint 900 °C.
13. Gyártási eljárás bevont lemez előállítására, amelynek során a 10-12 igénypontok bármelyike szerinti lágyított, hidegen hengerelt lemezt környezeti hőmérsékletre hűtjük, mielőtt bevonnák cinkkel vagy cink ötvözetrel.
14. Gyártási eljárás bevont lemez előállítására, amelynek során a 10-13 igénypontok bármelyike szerinti lágyított, hidegen hengerelt lemezt tűzi galvanizálással bevonjuk cinkkel vagy cink ötvözetrel, mielőtt lehűtenénk azt a környezeti hőmérsékletre.
15. A 10-14. igénypontok bármelyike szerinti lágyított, hidegen hengerelt lemez alkalmazásával előállított bevont acéllemez előállítására szolgáló gyártási eljárás, ahol a lágyított hidegen hengerelt lemezt alumíniummal vagy alumínium ötvözetrel vonjuk be tűzi horgonyzással/alumíniumozási eljárással mielőtt lehűtenénk azt a környezeti hőmérsékletre.
16. Gyártási eljárás bevont előállítására a 10-15. igénypontok bármelyike szerinti lágyított hidegen hengerelt lemez alkalmazásával, ahol a lemezt ismét hidegen hengereljük 0,1 és 3% közötti hengerlési fogyással.
17. Gyártási eljárás lágyított, hidegen hengerelt, és adott esetben a 10-16. igénypontok bármelyike szerinti bevont lemez előállítására, amelynek során az említett lemezt 150 °C és 190 °C közötti T_{hossz} hőmérsékletre

ten lágyítjuk és 10 óra és 48 óra között hőn tartjuk.

18. A 10. igénypont szerinti lemezből készült alkatrész előállítására szolgáló gyártási eljárás, amelynek során miután T_{soaking} hőmérsékleten lágyítottuk és mielőtt V_c sebességgel lehűtöttük, a lemezt melegen sajtoltjuk.
19. Az 1-9. igénypontok bármelyike szerinti lágyított, és hidegen hengereelt lemez alkalmazása vagy a 10-18. igénypontok bármelyike szerinti eljárással előállított lemez alkalmazása járműalkatrészek előállítására.