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STEEL

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My invention relates to rimmed steels, and, more particularly, it relates to rimmed steels having non-aging characteristics.

It has been known for some times that steels could be prepared having non-aging characteristics by subjecting them, while in the liquid state, to the action of strongly deoxidizing substances, such as aluminum, titanium, and zirconium, these elements being used in amounts sufficient to effect substantially complete deoxidation, i. e., to fully "kill" the steel.

Rimming steels, as is well known, are effervescing steels which "boil" actively in the mold after pouring. This "boiling" is caused by the vigorous evolution of CO gas due to the reaction between carbon and the iron oxide in the steel. Obviously, rimming steels are markedly different from killed steels, in that killed steels (especially when fully killed to make them non-aging) contain little, if any, oxide, while rimming steels must contain considerable oxide to produce the boiling action just referred to.

As is well known, there are certain definite advantages in producing a rimming steel instead of a killed steel. For one thing, there is considerably less pipe in rimmed steel than in killed steel, an ingot of rimmed steel therefore requiring less cropping than does killed steel. Prior to my invention, however, rimmed steels have not been non-aging.

I have discovered that by the use of substances which combine readily with nitrogen but which do not act as strong deoxidizers I can render steels non-aging without killing. I have found that vanadium is particularly advantageous in this respect as, when added in particular amounts to a rimming steel, the steel is rendered non-aging without interfering with the rimming action. As will appear later, the addition of vanadium not only produces a non-aging, rimmed steel, but also contributes other advantageous properties. My invention, therefore, comprises the addition of vanadium or equivalent substance to rimming steel whereby the steel is rendered non-aging without losing the characteristics and advantages of rimming steel.

In describing my invention, I shall first give, as an illustration, the use of vanadium. In preparing my steel, the steel is refined in the furnace in accordance with standard practices accepted for the making of rimming steels. As well known, the refining of rimming steels involves the use of strongly oxidizing conditions thereby to produce a steel sufficiently low in carbon, say, of the order of .07%, and with a very low silicon content which ordinarily will be below .01%. In accordance with standard rimming practices, deoxidizers, such as aluminum, manganese and silicon, are added, if necessary, to the ladle or to the mold to control the rimming action.

To the steel in the ladle or in the mold I add vanadium in amount sufficient to give the steel a vanadium content of from .01% to .15%. The vanadium may be introduced in any suitable form. For example, I have found it very effective to add vanadium as the standard grade of 40% ferro-vanadium. The vanadium may also be introduced as vanadium pent-oxide or as sodium or calcium vanadate. Better recoveries are obtained when using ferro-vanadium than when using compounds such as vanadium oxide, i. e., a greater percentage of the vanadium added becomes a constituent of the final product. When adding vanadium in the form of ferro-vanadium, recoveries range from 60% to as high as 90% of the vanadium added. When using vanadium oxide, V_2O_5 , recoveries may be obtained close to 50%.

Preferably the vanadium, regardless of the form in which it is used, is added to the ladle during tapping of the heat or to the molds during pouring of the ingots. In adding vanadium to the ladle better recovery of vanadium is secured if it is added after the ferro-manganese and after the addition of small amounts of aluminum or silico-manganese which latter are used to help to control the degree of rimming action. In some cases it is more efficient to add a portion of the vanadium to the ladle during tapping and a portion to the molds during pouring of the ingots.

I have found that a very high degree of resistance to age-hardening is obtained when the rimmed steel has a content of .03% vanadium or greater, up to .15%. For example, by adding one pound of vanadium in the form of 40% ferro-vanadium, to the ladle the resulting steel contains about .03% of vanadium. Such a steel, when tested, shows non-aging characteristics equal to those of fully aluminum killed steel. Yet such steel has all the essential characteristics of rimmed steel, and all of the procedural advantages of rimming are obtained. When tested at different temperatures for tensile strength a sample of this steel gave the following results:

V added	V content	Tensile strength, lbs. per sq. in.		
		Tested at room temp.	Tested at 400° F.	Change
1#/ton V in ladle as 40% ferro-vanadium	Per cent .032	44,900	38,600	-6300

To those skilled in the art it is obvious that the decided decrease in tensile strength from room temperature to 400° F. indicates this steel to have excellent non-aging characteristics. When a sheet of steel prepared from this steel was

skin-passed to about 1% elongation, and aged at 212° F. for 24 hours, the following results were obtained:

	As skin passed	As aged at 212° F. for 24 hours
Yield strength.....lbs. per sq. in.	30,000	30,300
Elongation at yield point.....per cent.	0	0
Rockwell B hardness.....	46	46

This shows clearly the excellence of this material as regards its non-aging properties.

My steel has excellent properties when used as sheet for operations involving deep drawing. Sheet material can be made of my steel in the regular way, involving the usual rolling operations and annealing, and then, if desired for particular purposes, it can be deep drawn. My steel has a particularly satisfactory structure for the deep drawing operation. It has a fine grain near the surface and a somewhat coarser grain in the interior. This condition is the reverse of that in ordinary rimmed steel sheet and renders the material particularly adapted for deep drawing. In this connection, it is to be pointed out that rimmed steel sheet has a better surface than that of killed steel. In my vanadium-containing rimmed steel, the surfaces of sheets were noticeably smoother, and with fewer defects, than the surface of non-aging fully killed steel sheets.

Although, as I have pointed out, a high degree of non-aging characteristics can be obtained when rimmed steel contains from .03% to .15% of vanadium, it is not always essential that steels possess such a high degree of non-aging. Therefore, I find it feasible, for certain purposes, to introduce smaller amounts of vanadium, getting a lesser degree of non-aging but still sufficient for certain purposes. For example, I may add from one-quarter to three-quarters of a pound of 40% vanadium for each ton of steel and thereby lessen the aging tendencies the necessary degree for many purposes. In contrast with this condition of partially overcoming the aging tendencies by adding vanadium to rimming steels, we have the condition in killed steels that it is

essential that the steel be completely killed. The minimum amount of vanadium used in my invention, however, should be such as not to give a vanadium content in the steel substantially less than .01%. Obviously, my invention is not limited to the manufacture of sheet steel, although it is very advantageous in that application. All kinds of rimmed steel, of varying carbon contents, may be made non-aging in the way described. In rimmed steel the surface is lower in carbon than the interior and the surface is therefore softer. Thus my vanadium-containing rimmed steel is advantageously used in fire-box steels, boiler steels, structural steels to be galvanized, etc., these steels being less liable to brittleness and cracking in bending and other types of deformation than with non-aging killed steels.

While I have found vanadium to be particularly advantageous as an addition to rimmed steel, I may also use other materials which are effective to combine with nitrogen in the steel but which do not act as strong deoxidizers. For example, I may use chromium which combines fairly readily with nitrogen but which, at the same time, is a mild deoxidizer. Amounts of chromium may be used of the order of .3%, giving an effectively rimming steel with substantial non-aging characteristics. After suitable annealing, sheet made of this steel is sufficiently soft for satisfactory deep drawing.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A steel having the characteristics due to rimming, containing vanadium between .01% and .15%, said steel having non-aging characteristics.

2. A steel having the characteristics due to rimming, containing vanadium between .03% and .10%, said steel having non-aging characteristics.

3. A steel having the characteristics due to rimming, containing vanadium between .01% and .15%.

4. A deep drawing sheet steel having the characteristics due to rimming and annealing, containing vanadium between .01% and .15%.

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