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STEEL FOR DRAWING, AND METHOD OF MANUFACTURING THIS STEEL

Pierre Wacquez, Liege, Belgium, assignor to S.A. Metallurgique d'Esperance-Longdoz, Liege, Belgium

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5 Claims. (Cl. 75—125)

It has always been admitted by metallurgists and technicians that the metallic impurities present in steel, such as copper, tin, nickel and chromium, impair the quality of thin plates adapted to be used for deep drawing. Manufacturers of steel plates therefore make a common practice of strictly limiting the amount of these impurities contained in products intended for deep drawing. It is usual for instance to limit the copper content of steel to 0.100%, or else to limit the total quantity of metal impurities to a predetermined value, since the quality of the steel, in respect of its suitability for drawing, deteriorates when the quantity of metallic impurities increases.

The present invention, which is concerned with the improvement of plates adapted to be used for deep drawing, uses a method which contravenes these generally accepted rules. This method consists essentially in very substantially increasing the copper content, as compared with the copper content that is generally regarded as admissible, in effervescent or rimmed steels of which the tendency to ageing has been made small by making the nitrogen content small or preferably practically zero, by making the carbon and nitrogen content very low.

The inventor has in fact found that the addition of copper, preferably in the proportions set forth hereinafter, to effervescent steels of this kind, produced the result that thin plates made from these steels, were exceptionally suitable for drawing, as shown by an exceptional ratio of the diameter of the disc to the diameter of the drawn object, by the total absence of folds, by remarkable resistance to fracture after drawing and by very slight ageing with time.

A first experiment was concerned with steels made in a basic converter and partly blown with a mixture of oxygen and steam.

These steels gave the following average analysis:

	Percent
C	0.055
Mn	0.320
P	0.017
S	0.013
N_2	0.002
Ni	0.026
Cr	0.008
Sn	0.008

Copper was added to bring the amount of this element up to between 0.25 and 0.45%. Cold-rolled plate made from this steel was tested in the laboratory and was found

to have the following mechanical properties (eight days after skin-pass: transverse test-pieces: thickness 1.0 mm.):

Elastic limit	kg./mm²	23.5
Breaking load	kg./mm²	34.1
Elongation	percent	[1] 36.2
Erichsen	mm	10.7
Hardness (RB)		56

[1] Two-inch test-piece.

These characteristics are not at all remarkable for a steel intended for drawing. Contrary to all expectation, however, exceptionally good results were obtained when this material was drawn.

This suitability was judged by comparison with other plates made from effervescent steel and killed steel, in two series of tests by drawing flat-bottomed cylindrical cups. The first series was carried out in accordance with the standards proposed by the "Swift-Cup-Forming Sub Committee of BISRA." The second series was carried out by press-drawing discs of increasing diameter, by means of plungers having a diameter of eighty millimeters, with flat bottoms and with hemispherical bottoms. In all of these tests, the suitability for drawing is determined by the diameter of the disc that can be drawn with more than 80% chance of success. The "drawability index" is defined as the ratio of the maximum diameter of the disc to the diameter of the plunger.

Liability to breakage by fracture was determined, in comparison with other effervescent steels and killed steels, by means of an operation in which the cast object was crushed by compression either immediately after drawing or after natural ageing for several weeks.

The following table shows the performances of the various steels.

The Fukui test referred to in these tables is described in "The Conical Cup Test as a Method of Testing the Drawing and Forming Qualities of Sheet Steel (part III), December 1958," published by The Conical Cup Test Research Group, c/o Institute of Physical and Chemical Research, Komagame, Bunkyo-ku, Tokyo. In this test, a circular disc of given diameter is drawn, by means of a hemispherical plunger, on a cylindroconical die without means for gripping the disc. It is necessary on the one hand to avoid the formation of folds (which implies a decrease in the diameter of the disc when the thickness of the sheet material decreases) and on the other hand to respect the rules of similitudes, and it is therefore necessary to work with five sets of apparatus in order to test metal sheets of which the thickness varies between 0.5 and 1.6 mm.

The suitability of given sheet metal for drawing is determined by drawing a disc having a particular diameter, until the disc breaks, and then measuring the reduced diameter, that is to say, the mean diameter of the base of the conical part of the cup after fracture.

The quotient obtained when this reduced diameter is divided by the initial diameter of the disc, is called the drawing ratio

$$\left(n_0 = \frac{Dr}{Di}\right)$$

It decreases as the suitability for drawing increases.

"Drawability" and fragility tests

Normal annealed steel (715°)	Tests 15 days after skin-pass				Tests 2 months after skin-pass—Test with 80 mm. diameter press plunger		
	Fukui Test Discs of 60 mm. critical diameter	Swift Test 32 mm. diameter, *D/d*	Test with flat-bottomed press plunger diameter 80 mm., *D/d*	Fragility	Flat bottom, *D/d*	Hemispherical bottom, *D/d*	Fragility
Effervescent (blown with enriched air), N_2: 0.007.	46.50	2.29	2.16	Very fragile			
Effervescent (blown with oxygen and steam), N_2: 0.002.	45.85	2.28	2.15	Not fragile	2.16	2.16	Not fragile.
Killed	44.87	2.34	2.22	do	2.21	2.27	Do.
Effervescent with copper (blown with oxygen and steam), N_2: 0.002.	44.94	2.38	2.26	do	2.26	2.35	Do.

NOTE.—In this table the term *D/d* is the drawing ratio wherein D is the diameter of the blank and *d* is the diameter of the drawn material.

The present invention, resulting from this discovery, relates to plates for drawing and/or steel for drawing, characterized both by a predetermined magnitude of the copper content and by very small amounts of nitrogen or, preferably, carbon and nitrogen.

The mechanical properties of this steel, wherein E is the elastic limit, R is the tensile strength, A is the percent elongation, and the vermiculation index is a measure of the surface roughening is as follows:

Mechanical properties after annealing

[Thickness 1.0 mm.]

	Tensile test (parallel two-inch test-pieces)				RB Hardness	*E/R*
	E, kg./mm.²	R, kg./mm.²	A, percent	Vermiculation index		
After skin-pass:						
Normal annealing	21.4	33.2	36.2	1	55	0.64
Annealing with wet hydrogen	16.2	30.1	45.0	0	45	0.54
After artificial ageing (1 hour at 100°):						
Normal annealing	22.3	33.0	36.6	1	55	0.66
Annealing with wet hydrogen	17.0	30.0	43.8	0	47	0.56

According to the invention, the copper content that produces the best properties is between 0.250 and 0.450%, whereas the nitrogen content must be as low as possible, and in all cases less than 0.0035%.

The invention is also concerned with practical methods of manufacturing this type of steel.

One of these consists in making very mild effervescent steels containing very little nitrogen (N_2 less than 0.0035%, and preferably less than 0.0020%), in a converter blown from below with a mixture of oxygen and steam or a mixture of oxygen and CO_2, or in a converter blown from above with oxygen technically free from nitrogen, and in bringing the copper content to between 0.250 and 0.450% by adding copper or by the selection of the blast furnace charge or the converter charge.

A second method consists in making, by any suitable means, a mild effervescent steel of which the copper content is between 0.25 and 0.45% and then, after the plates have been rolled, in subjecting the plates to a nitrogen- and carbon-removing annealing operation in an atmosphere consisting mainly of wet hydrogen, which reduces the nitrogen and carbon content to less than 0.0010% and 0.010% respectively.

For instance, plates giving the following analysis were obtained by this latter method:

	Percent
C	0.005
Mn	0.35
P	0.020
S	0.015
N_2	0.0005
Cu	0.420
Ni	0.035
Cr	0.009
Sn	0.011

These steels gave the following excellent results in the Fukui test.

Fukui test

[Critical disc diameter of 60 mm.]

Normal annealing (700°)	45.53
Annealing with wet hydrogen (700°)	45.28

I claim:

1. Mild steel suitable for deep drawing having a rimmed structure, said steel containing between 0.25 and 0.45% of copper, less than 0.0010% of nitrogen, less than 0.010% of carbon, between 0.20 and 0.45% manganese, less than 0.030% of phosphorus, less than 0.025% of silicon, a total of less than 0.15% of other impurities and the remainder being iron.

2. Mild steel as claimed in claim 1, containing less than 0.0007% nitrogen.

3. Mild steel as claimed in claim 1, containing less than 0.006% carbon.

4. Mild steel as claimed in claim 1, containing less than 0.0007% nitrogen and less than 0.006% carbon.

5. Plate material consisting of steel as claimed in claim 1.

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DAVID L. RECK, *Primary Examiner.*

MARCUS U. LYONS, *Examiner.*