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HOT DUCTILITY OF STEELS CONTAINING TELLURIUM

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ABSTRACT OF THE DISCLOSURE

Minimizing the loss in ductility at elevated temperature resulting from the additions of tellurium to steels by providing the steels with rare earth metals in predetermined amounts with the tellurium.

This invention relates to the improvement in the hot ductility of steels containing tellurium.

It is known that lead, bismuth, sulphur, selenium or tellurium improve the machinability of steel when added in small amounts. It is desirable to make use of tellurium as an additive to improve the machinability of such steels because small amounts of tellurium improve the machinability while having little or no adverse effects on other properties of the steel parts produced.

However, tellurium, even when present in small amounts, has an effect on the steel which is unique by comparison with the additions of lead or selenium in amounts to improve machinability. The presence of tellurium in the steels in the amounts required to improve machinability has the very undesirable effect of reducing ductility of the steel at hot working temperatures.

This problem is illustrated by the following results secured in AISI 4142 steel to which tellurium, selenium and lead have been added separately in amounts to improve machinability. The steels that were tested had the following analyses:

TABLE 1

Chemical Compositions of Steels Tested for Percent Reduction in Area

	Composition, percent, of—			
	Example 1	Example 2	Example 3	Example 4
Carbon	0.47	0.48	0.48	.37
Manganese	0.88	0.95	1.12	.87
Phosphorus	0.015	0.014	0.016	.022
Sulphur	0.018	0.023	0.021	.015
Silicon	0.33	0.30	0.32	.09
Nickel	0.16	0.15	0.14	0.15
Chromium	1.00	1.00	0.98	0.91
Molybdenum	0.18	0.18	0.16	0.20
Copper	0.15	0.16	0.14	0.15
Tellurium		0.08		
Selenium			0.08–0.11	
Lead				0.15
Special element	None	Te	Se	Pb

Hot tensile tests were performed on the wrought steels on conventional tensile testing equipment with conventional samples heated to temperatures of 1,900° F., 2,050° F. and 2,200° F. for testing. The following are the results that were secured:

TABLE 2.—HOT TENSILE TESTS

	Reduction in area in percent at—		
	1,900° F.	2,050° F.	2,200° F.
Example:			
1	94.3	99.4	98.7
2 (Te	44.1	77.4	69.8
3 (Se)	94.6	88.7	99.3
4 (Pb)	99.7	94.4	98.5

It will be seen from the foregoing that the hot ductility of the steels containing tellurium was markedly lower by comparison with the same types of steels containing

selenium or lead. While the presence of lead or selenium appears to have no harmful effect on hot ductility of the steels, the presence of tellurium, especially at hot working temperatures, results in a susceptibility to cracking during rolling, extrusion or other types of hot working; such steels require more surface conditioning; and they give lower yields of good bar stock per unit weight of ingot. No metallurgical explanation is yet available to explain this unexpected characteristic which appears to be unique to tellurium but similar effects on hot ductility are experienced with others of the plain, medium and high steels and alloys thereof.

It is an object of this invention to produce and to provide a method for producing plain, medium and high carbon steels and alloy steels in which use is made of tellurium in amounts to improve machinability characteristics of the steels but in which the undesirable effect of tellurium on the ductility of the steels at hot working temperatures is effectively overcome.

It has been found in accordance with the practice of this invention that the introduction into the steel of one or more rare earth metals as an alloying element is effective in combination with tellurium to overcome the undesirable effects of tellurium on the ductility of the steel at elevated temperatures. The effect of rare earth elements to overcome the effect of tellurium on hot ductility is capable of development with plain, medium and high carbon steels with or without alloy additions. It is also capable of development with killed steel in which, for example, aluminum and/or silicon have previously been added to the molten steel for removal of oxygen.

In the combination which makes use of one or more of the rare earth elements with tellurium, tellurium is added to yield a tellurium content in the steel in an amount within the range of .01 to .10 percent by weight and preferably in an amount within the range of .02 to .085 percent by weight. The amount of tellurium can be obtained by additions of tellurium, preferably in the form of a ferro tellurium, to the molten steel preferably before pouring the ingot.

In the commercial practice of this invention, the rare earth component is preferably added in the form of mischmetal which is a mixture of rare earths containing about 50 to 53 percent by weight cerium, 25 to 26 percent by weight lanthanum, about 5 percent by weight praseodymium, and about 16 percent by weight neodymium. However, any one or more of the rare earths may be employed alone or in admixtures. The desired results can be secured when the mischmetal or other rare earths are employed with the tellurium in the ratio of 100 parts by weight tellurium to 10–5000 parts by weight of rare earths, and preferably in the ratio of 100 parts by weight tellurium to 40–1000 parts by weight of rare earths. With respect to the content of rare earths in the steel, the desired results are secured when the rare earths are present in the steel in an amount within the range of .01–.5 percent by weight and preferably .02–.1 percent by weight.

The significance of the presence of rare earths in steels containing tellurium can best be illustrated by the following examples.

In these tests, the steels were made up in an induction furnace with a magnesia lining. The charges to the furnace were made up of ingot iron and ferrosilicon. Immediately after the charge was melted, ferro alloys were added to increase the silicon, chromium, phosphorus and molybdenum content. After the slag was skimmed off, ferrosilicon was added with graphite to control the carbon and silicon contents. Three minutes after carbon addition, ferro-manganese was added. The additions of aluminum to kill the steel and the additions of tellurium and mischmetal, when called for, in the amounts to give the volumes set forth in the following tables, were made with the manganese. After about 12–16 minutes, the metal was poured at a temperature of 2920°–3000° F.

In the tables which follow, the rare earth content was analyzed on the basis of cerium content. Assuming the cerium represents 50 percent of the total rare earths in mischmetal, the total amount of rare earths would be approximately twice the amount analyzed for cerium.

The hot tensile tests reported were performed on an apparatus, known as a Gleeble, on test specimens in the form of rods having a diameter of 0.250 inch and a length of 4⅛ inches. The test specimens, as cast, were heated in air by electrical resistance means in acordance with the following heating schedules:

Schedule A—The test specimens were heated to 2275° F. in 20 seconds, held at this temperature for 120 seconds, and then cooled to test temperatures of 1900° F., 2050° F. and 2200° F. in about 10 seconds, and held at test temperature for about 10 seconds before pulling.

Schedule B—The test specimens were heated directly to test temperatures of 1900° F., 2050° F., and 2200° F. in about 20 seconds and held at test temperature for 10 seconds before pulling.

The hot tensile tests were performed with a head separation speed of 2 inches per second, thus giving an initial strain rate of 40 percent/second.

ratio of 1 part by weight tellurium to .25 to 10 parts by weight of rare earth.

3. The method as claimed in claim **1** in which the tellurium is present in the steel in an amount within the range of .01 to 0.1 percent by weight and the rare earth element is present in an amount within the range of .01 to .5 percent by weight of the steel.

4. The method as claimed in claim **1** in which the tellurium is present in the steel in an amount within the range of .02 to .085 percent by weight and the rare earth element is present in an amount within the range of .02 to 0.1 percent by weight of the steel.

5. The method as claimed in claim **1** in which the rare earth element is introduced in the form of mischmetal.

6. The method as claimed in claim **1** in which the tellurium and the rare earth element are both introduced into the molten steel after others of the alloying elements have been added and approximately immediately prior to pouring.

7. The method as claimed in claim **1** which includes the step of hot working the steel.

8. The method of hot working steels containing tellurium without loss of ductility or increased cracking comprising hot working a steel to which rare earth elements have been added, as in claim **1**.

9. A plain, medium, or high carbon steel, with or without additional alloying elements and which is impaired in

TABLE 3

	Steel composition										Reduction in area, percent					
											Heated to 2,275° F. cooled to test temp. of—			Heated directly to test temp. of—		
	C	Mn	P	S	Si	Cr	Mo	Al	Te	Ce	1,900 °F.	2,050 °F.	2,200 °F.	1,900 °F.	2,050 °F.	2,200 °F.
Example:																
5	.42	.82	(0.02)	(.02)	.27	1.05	0.20	(.05)			83.5	98.9	91.7	94.2	94.0	98.8
6	.41	.90	(0.02)	(.02)	.29	1.08	0.20	(.05)	.083		22.0	24.5	72.6	22.0	19.2	32.2
7	.37	.86	.022	.020	.27	0.95	0.20	.044	.049	.018	38.4	58.7	95.8	31.0	34.3	94.9
8	.34	.91	(.02)	(.02)	.27	0.96	0.20	.040	.072	.018	82.8	94.8	65.3	50.1	91.2	96.6
9	.36	.88	.023	.020	.09	0.94	0.21		.047	.012	37.8	78.0	80.0	36.8	51.0	87.6
10	.38	.91	(.02)	(.02)	.10	0.95	0.20		.085	.009	55.5	84.0	98.7	56.8	63.7	95.8

It will be seen from the foregoing data on 4140 type steels that the presence of tellurium drastically reduces the hot ductility of wrought and killed steels. This is reflected in rolling wherein the reduced ductility while hot causes tears and excessive cracking with corresponding increase in the amount of unacceptable steel or scrap.

The beneficial effects of mischmetal or rare earth elements on hot ductility of tellurium containing steels is clearly evident in every case and in both heating schedules with the effect being most pronounced in the improvements that are shown at metal temperatures of 1900° F. and 2050° F. by comparison with the higher temperature of 2200° F.

The foregoing is believed clearly to demonstrate the beneficial effects that are secured when rare earth metals are added for retention in 4140 type steels to which tellurium has been added. Similar effects are secured with other types of steels such as 4142, 1045, 1215 and stainless steels as well as conventional plain carbon steels, medium carbon steels and high carbon steels and such steels containing alloying elements and in which tellurium is provided for the purpose of improving machinability or the like.

It will be understood that changes may be made in the details of the metallurgical processing steps and techniques as well as steel compositions without departing from the spirit of the invention, especially as defined in the following claims.

I claim:

1. The method of improving the hot ductility of steels containing tellurium comprising adding rare earth elements for retention in the steel in the ratio of 1 part by weight tellurium to .1 to 50 parts by weight of rare earths.

2. The method as claimed in claim **1** in which the rare earth element is added for retention in the steel in the

hot ductility by reason of the presence of tellurium in which the steel contains tellurium in an amount within the range of .01 to 0.1 percent by weight and rare earths in the ratio of 1 part by weight tellurium per .1 to 50 parts by weight of rare earth element.

10. A steel as claimed in claim **9** in which the rare earth is present in the ratio of 1 part by weight tellurium to .25 to 10 parts by weight of rare earth element.

11. A steel as claimed in claim **9** in which tellurium is present in an amount within the range of .01 to .10 percent by weight and the rare earth element is present in an amount within the range of .01 to .5 percent by weight.

12. A steel as claimed in claim **9** in which tellurium is present in an amount within the range of .02 to .085 percent by weight and the rare earth is present in an amount within the range of .02 to .10 percent by weight.

13. A steel as claimed in claim **9** in which the rare earth is a mixture of rare earth elements.

14. A steel as claimed in claim **9** in which the rare earth is in the form of mischmetal.

15. A hot worked tellurium steel having 0.1 to 50 parts by weight rare earth per 1 part by weight tellurium to improve the hot ductility of the steel.

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U.S. Cl. X.R.

75—123 E, 126 G, 126 M, 128 E, 128 P, 129; 148—12, 36

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,679,400 Dated July 25, 1972

Inventor(s) Elliot S. Nachtman

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

column 3, line 27, change "40" to "400".

Signed and sealed this 19th day of December 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents