

[54] APPARATUS FOR PRODUCING WIRE FROM THE MELTS OF STEEL ALLOYS

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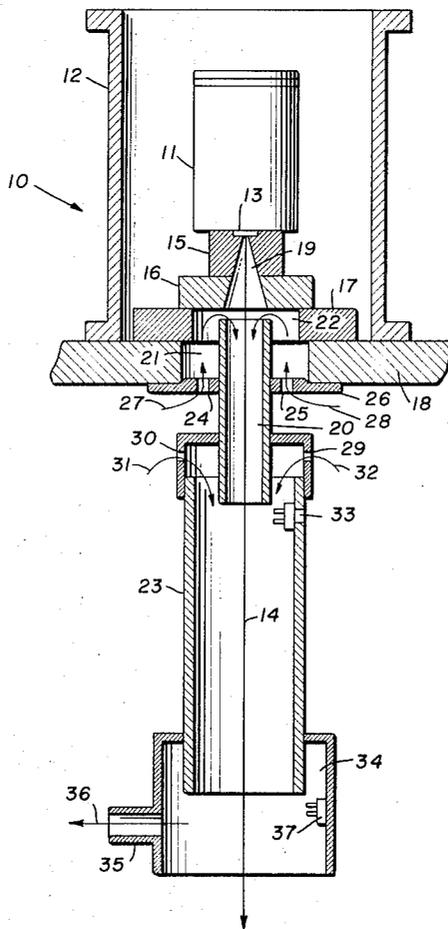
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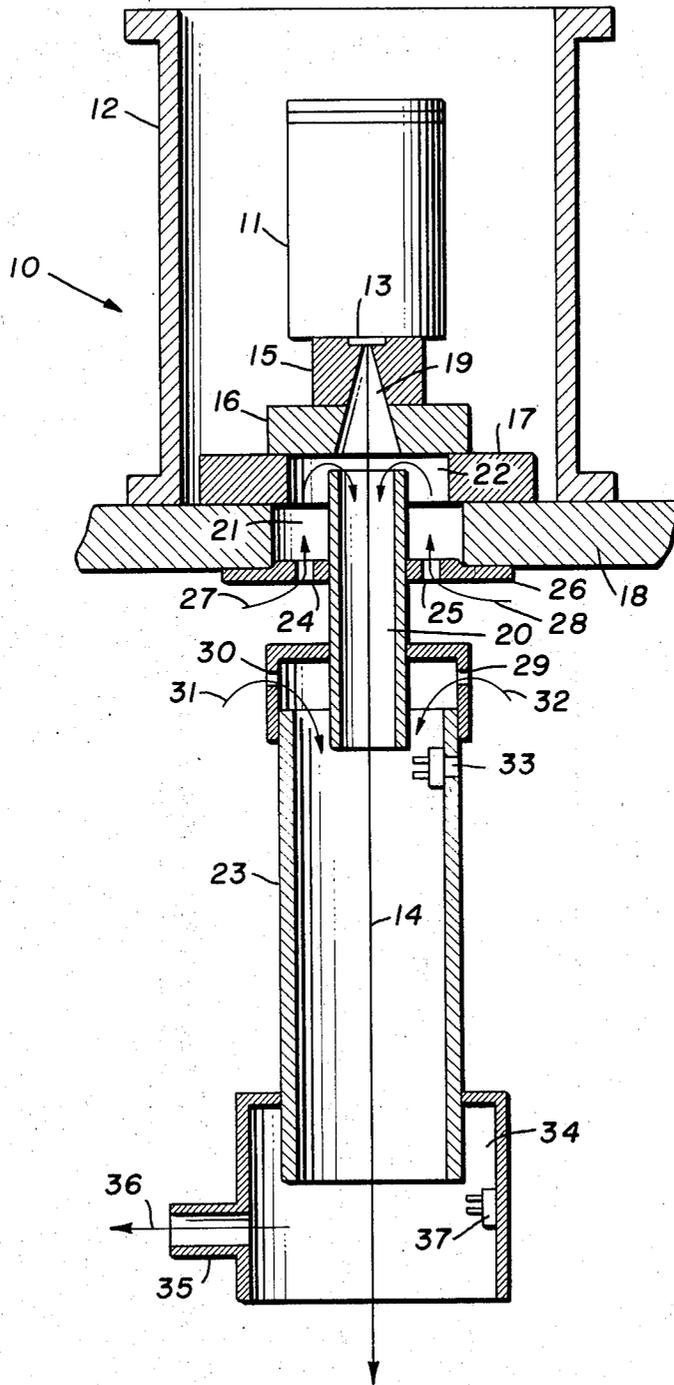
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[57] ABSTRACT

An improved apparatus is provided for producing wire from steel alloys by extrusion from the melt. Specifically, the improvement resides in an assembly which permits the effective use of gaseous hydrogen as a quenching medium for cooling the extruded molten metal stream to effect solidification. The assembly includes a first cooling chamber into which hydrogen is introduced for an initial rapid cooling and a second cooling chamber into which a flow of air is admitted for producing a combustible gas mixture with the hydrogen coolant. The upper end of the first cooling chamber is positioned to receive the molten stream as it issues from the extrusion apparatus while the lower end extends into the second cooling chamber and terminates proximate to its entrance. The hydrogen passes from the first cooling chamber into the second cooling chamber in co-current flow with the molten metal stream. The hydrogen is then burned either at the exit of the first or second cooling chamber while the solidified wire is forwarded to a take-up device upon exiting from the second cooling chamber.

5 Claims, 1 Drawing Figure





APPARATUS FOR PRODUCING WIRE FROM THE MELTS OF STEEL ALLOYS

FIELD OF THE INVENTION

This invention relates to the manufacture of fine diameter wire directly from the melt of steel alloys by extruding a free-streaming molten jet which upon solidification yields a solid filamentary product. More specifically, the invention is concerned with an improved method and apparatus for cooling the extruded molten stream to effect solidification. Fine diameter wire is defined as wire having a diameter of less than about 35 mils.

BACKGROUND OF THE INVENTION

In the production of filaments and wire from steel alloys by the process of melt extrusion, the melt is forced through a small orifice and into an oxygen-containing medium as a continuous molten stream. This results in an instantaneous reaction causing the formation of an oxide skin or film about the periphery of the hot jet immediately upon issue from the extrusion orifice. The purpose of the film, referred to as the "stabilizing film," is to protect the liquid stream against surface tension break-up until solidification can be effected by cooling.

In order that the stabilizing film be capable of functioning in the intended manner, the oxide formed must be stable and insoluble in the melt. Because the oxide of iron does not possess these required properties, it is necessary that a second alloying metal be added to the melt before steel can be satisfactorily processed by this method. That is, a second metal is added whose oxide is stable and insoluble in the molten charge. Aluminum and silicon have been most commonly used for this purpose, although various other metals, e.g., magnesium, beryllium, chromium, lanthanum and titanium are likewise capable of forming the desired oxide film. The second metal is present in only very minor amounts, say from about 0.3 to 5.0 percent on the weight of the alloy, with from 1.0 to 2.0 percent being most generally used.

After the extruded molten stream or jet has been film stabilized, it is rapidly quenched to effect solidification. Previously, this has been accomplished by causing the stabilized stream as it emerges from the extrusion unit to pass through a chamber which is continuously supplied with a quenching medium of helium gas. Although this cooling system has been reasonably effective, the high cost of helium has had an adverse impact on over-all process economics. Consequently, there has been a need and a desire for a more economic gaseous cooling medium which could be satisfactorily substituted for high cost helium.

Any gas used for this purpose must possess, as does helium, a high coefficient of heat transfer and be chemically inert to the liquid stream under the conditions of the quenching operation. Hydrogen, which is relatively inexpensive when compared with helium, is known to have such properties. Moreover, in actual trial runs hydrogen has been found to perform even more efficiently than does helium as a heat transfer agent in the quenching operation.

Despite these advantages, it has not been previously practical or even feasible to utilize hydrogen as a cooling medium in continuous production operations. The reason for this has been its tendency to cause a tempo-

rary reduction in the tensile properties of the wire product at the time of solidification, i.e., the wire exhibits a tensile strength when formed which is from 30-40 percent below normal levels. This phenomenon is believed to be caused by the presence of interstitial hydrogen which has diffused into the wire during the cooling procedure. Apparently, the hydrogen slowly diffuses out of the wire product when at ambient temperatures, since the tensile properties generally recover to normal levels in from about 24-36 hours at room temperature. Nevertheless, the drastic reduction in tensile strength at the time the wire is formed causes great difficulty in take-up. That is, the low strength, embrittled wire can not be handled as required for continuous collection on take-up devices.

It is, therefore, an object of this invention to provide a procedure which permits the effective utilization of gaseous hydrogen as a quenching medium in the continuous production of steel alloy wire by extrusion from the melt.

It is a further object of the invention to provide a method and apparatus for hydrogen cooling in the manufacture of steel alloy wire by melt extrusion wherein the tensile properties of the wire product at the time of formation are at levels compatible with continuous take-up.

SUMMARY OF THE INVENTION

The afore-mentioned objects are achieved by a procedure wherein the accumulation of interstitial hydrogen in the extruded wire prior to take-up is substantially eliminated. As a result, the tensile strength of the solidified wire is relatively unimpaired and collection on take-up devices can be conducted in the normal manner.

This is accomplished by a controlled exposure of the extruded wire to the hydrogen quenching medium while cooling to effect solidification. The time in which the wire is in contact with hydrogen is controlled by burning the spent hydrogen after an appropriate predetermined interval of contact. By limiting the extent of exposure to the coolant, diffusion of the hydrogen into the interstices of the wire is greatly reduced. Moreover, such control permits cooling of the wire to a temperature level which is still high enough to cause any interstitial hydrogen present therein to diffuse out at an accelerated rate before reaching the take-up mechanisms.

In practicing the present invention, the hot molten jet issuing from an extrusion unit enters a first cooling zone where initial contact is made with the gaseous hydrogen coolant. The hydrogen which is continuously supplied into the entrance of the zone at a predetermined flow rate passes through the zone in co-current flow with the free-streaming molten jet. From this first cooling zone, the jet and enveloping flow of hydrogen exit directly into a second cooling zone into which air is continuously supplied. The air is admitted proximate to the entrance of this second zone at a predetermined flow rate and flows in a direction co-current with that of the extruded jet and the hydrogen coolant. Commingling of the gaseous hydrogen coolant with the flow of air causes a combustible gas mixture to form which is ignited by passage through a continuous flame. The products of combustion are exhausted from the second cooling zone at its terminal end while the solid wire

product exiting therefrom is continuously forwarded to take-up devices.

In a preferred embodiment the flow of hydrogen and air into the system is adjusted such that upon admixture in the second cooling zone, the hydrogen present in the resulting mixture exceeds the stoichiometric quantity for total combustion with the amount of air present by from about 10-18 percent. In addition, ignition of the gaseous mixture is caused to occur within the second cooling zone at a point proximate to its entrance with the products of combustion being swept through the zone and exhausted at the terminal end.

The afore-described procedure may be carried out in an apparatus having a design as illustrated in the accompanying drawing. This novel apparatus can best be understood by the following description of the drawing.

DESCRIPTION OF THE DRAWING

The single FIGURE is a schematic sectional view of the presently preferred embodiment of the apparatus of this invention. There is shown, as generally represented by the numeral 10, a typical assembly for extruding a free-streaming molten jet from the melt of a steel alloy. The assembly includes a crucible 11 for containing the melt enclosed within a pressure vessel 12. The crucible is provided with an orifice 13 through which is extruded a continuous stream or jet of molten metal generally denoted 14. The crucible rests upon a supporting insulating pedestal 15 of pyrolytic graphite construction which in turn rests upon pedestals 16 and 17 supported by the assembly base plate 18. Upon emerging from orifice 13, the nascent molten jet passes through a reactive gaseous atmosphere contained within cavity 19 of pedestals 15 and 16 where a stabilizing film is formed about the peripheral surface of the molten stream or jet.

Positioned immediately beneath the conical stabilization zone formed by cavity 19 is a first vertically disposed elongated cooling chamber 20. The upper portion of chamber 20 extends into extrusion assembly 10 through cavity 21 in base plate 18 and terminates in cavity 22 of pedestal 17; while the lower portion extends into a second elongated cooling chamber or column 23 and terminates proximate to the entrance thereof. As shown in the drawing, cooling column 23 is of greater length and cross-sectional area than cooling chamber 20.

In operation, the extruded molten stream upon emerging from the stabilizing zone 19 enters cooling chamber 20 and passes through it together with a co-current flow of gaseous hydrogen which effects an initial rapid cooling. The hydrogen coolant is metered through apertures 24 and 25 in flange member 26 from a supply source (not shown) and is continuously admitted into the entrance of cooling chamber 20 via a flow path through cavity 22 in base plate 18 and pedestal 17 as indicated by arrows 27 and 28. Upon exiting from chamber 20 directly into cooling column 23, the downward descending molten stream 14 and enveloping flow of hydrogen are immediately brought into contact with a metered flow of air. The air which may be supplied by a blower or other means (not shown) is introduced proximate to the entrance of cooling column 23 through ports 29 and 30 and flows in a downward direction co-currently with the hydrogen flow as indicated by arrows 31 and 32. The intermingling of hy-

drogen with air forms a combustible gas mixture which is ignited by passage through a continuously burning hydrogen flame. Burning the gaseous hydrogen-air mixture is preferably conducted proximate to the exit of cooling chamber 20. The flame may be produced by an electrically activated spark plug 33 or other suitable means. The combustion products are swept downward through cooling column 23 and are utilized as co-current gas to provide necessary aerodynamic drag on the descending metal stream and additional cooling. Upon exiting from cooling column 23, the combustion products enter exhaust chamber 34 and are exhausted through conduit 35 as indicated by arrow 36 while the molten stream 14 now cooled to a solid wire product is continuously advanced to a take-up device.

A second ignition system 37 positioned at the exit of cooling column 23 is optional but provides a number of advantages. For example, it provides for the safe disposal of any hydrogen present in the combustion products exhausted at the exit of cooling column 23. Moreover, it provides an alternative site for an initial combustion of the hydrogen-air mixture. That is, in some instances it may be desirable and advantageous to effect combustion solely at the exit of cooling column 23, in which case, ignition system 33 would not be placed in operation.

DETAILED DESCRIPTION OF THE INVENTION

As has been noted in describing the drawing, a novel apparatus which may be employed in the practice of this invention comprises a first elongated cooling chamber 20 which communicates with a second chamber 23—the second chamber being of the greater length and cross-sectional area. The hydrogen coolant is metered into the entrance at the top of the first and shorter chamber 20 for initial rapid cooling of the free-streaming molten jet and is burned at the exit thereof after passing through in co-current flow with the molten wire stream. Air for combustion is admitted through the top of the cooling chamber 23. The combustion products are swept downward through chamber 23 to provide additional cooling and the necessary aerodynamic drag on the wire stream. Optionally, the gaseous hydrogen may be burned at the exit of cooling chamber 23.

The effective length of hydrogen cooling chamber 20 will vary depending for the most part upon the ejection velocity under which the molten metal is extruded. For extrusion rates up to 1,400 feet per minute, a length of about 16 inches has been found satisfactory. Chamber 23 into which the air for combustion is admitted should be of a greater relative length. That is, in the instance when the length of hydrogen cooling chamber 20 is about 16 inches, a length of from about 55 to 60 inches has been found suitable for the chamber 23. Generally speaking, the effective total length of hydrogen cooling chamber 20 and chamber 23 should be at least about 42 inches. A cylindrical or tubular configuration is usually preferred for both chambers 20 and 23, although this is not critical and other configurations could be used if desired.

As has been noted, the hydrogen quenching medium is continuously introduced into cooling chamber 20 to present a fresh cool supply along the path of the molten stream as it is extruded. The minimum effective flow rate of the hydrogen coolant is dependent upon the length of the chamber into which it is introduced, the

diameter of wire being extruded and the ejection velocity under which the molten metal is extruded. For any given set of such conditions, the appropriate flow rate can be readily determined by simple trial runs. The hydrogen flow rate controls the temperature of the wire as it exits from the hydrogen cooling chamber 20. That is, the temperature should be at a low enough level wherein solidification can be effected on further cooling in chamber 23 and yet high enough to induce an accelerated diffusion of hydrogen out of the wire prior to take-up.

The air flow rate into chamber 23 controls the degree of combustion of the hydrogen exiting from chamber 20. Since the temperature level required to accelerate diffusion of hydrogen out of the wire tends to promote the oxidation of the wire in the presence of air, it is generally desirable to adjust the air flow rate to provide less than the stoichiometric quantities required to effect total combustion of the hydrogen present. The purpose is to exclude oxygen from the combustion products being swept downwardly in chamber 23. Although not required, it is generally preferred that the hydrogen present exceed the stoichiometric quantity for combustion with the amount of air introduced into the system by from about 10-18 percent.

The following table presents data on a series of experimental runs in which either the hydrogen or air as delivered into the system was in stoichiometric excess for combustion. The notations under wire appearance indicate whether or not some oxidation occurred during the cooling operation.

Run No.	Wire Dia. (Mils)	Flow Rates		Excess H ₂ or air (%)		Wire Appearance
		H ₂ liter/min	Air liter/min			
1	4.1	10.1	25.9	8	air	very dark
2	4.1	10.0	21.2	11	H ₂	light
3	4.1	10.0	19.2	20	H ₂	very light but brittle
4	4.7	14.2	36.0	6	air	blue
5	4.7	14.2	28.0	18	H ₂	light

It is seen that undesirable oxidation was essentially avoided in runs 2, 3 and 5 where excess hydrogen was employed. However in run number 3 brittleness in the wire occurred when too great of an excess of hydrogen was employed. In conducting the runs reported in the above table the extrusion velocity was 1,200 feet per minute. The cooling chamber into which the hydrogen was injected had a length of 16 inches and the downstream chamber into which the flow of air was introduced had a length of 60 inches.

It is seen from the above description that the objects of this invention are well fulfilled by the method and apparatus of this invention. The description is intended to be illustrative only and it is to be understood that changes and variations may be made without departing from the spirit and scope of the invention as defined by the appended claims.

I claim:

1. In an apparatus for producing fine diameter wire directly from the melt of an alloy of steel wherein the melt is extruded as a molten metal stream directly into an oxygen-containing gaseous atmosphere where a sta-

bilizing film is formed about the peripheral surface of the stream, and wherein the stabilized molten metal stream descends downwardly through a cooling means where it is solidified to form a solid wire product, the improvement comprising an assembly for effecting said solidification with a cooling medium of gaseous hydrogen, said assembly being comprised of:

- a. first and second elongated, vertically disposed and intercommunicating cooling chambers, the upper end of said first cooling chamber being positioned immediately beneath the portion of the apparatus from which the stabilized molten stream issues to provide an entrance for receiving said stream, while the lower end of said first cooling chamber is positioned to extend into the upper end of said second cooling chamber and terminates proximate to the entrance thereof, said second cooling chamber being of greater length and cross-sectional area than said first cooling chamber;
- b. means for supplying hydrogen gas into the entrance of said first cooling chamber in co-current flow with said downwardly descending molten metal stream;
- c. means for introducing a flow of air into said second cooling chamber proximate to the entrance thereof to form a combustible gas mixture with said hydrogen gas as it exits from said first cooling chamber into said second cooling chamber;
- d. means for igniting said combustible gas mixture to cause combustion thereof; and

e. means for exhausting the products of said combustion upon exit from said second cooling chamber.

2. The apparatus of claim 1, wherein said first and second cooling chambers have a tubular configuration.

3. The apparatus of claim 1, wherein said ignition means is positioned in said second cooling chamber proximate to the exit of said first cooling chamber.

4. The apparatus of claim 1, wherein said ignition means is positioned proximate to the exit of said second cooling chamber.

5. The apparatus of claim 1, wherein a first ignition means is positioned proximate to the exit of said first cooling chamber and a second ignition means is positioned proximate to the exit of said second cooling chamber.