Metal powder is produced by atomizing a hollow stream of molten metal, using pressurized fluid from the inside or from the outside. The molten metal is atomized right when or shortly after flowing off a hollow mandrel, into which either the atomizing fluid or a sustaining fluid for the hollow stream is fed. Additional fluid jets redirect and/or additionally atomize the droplets as formed and flow-directed by the principle atomizing process.
METHOD FOR MAKING METAL POWDER

BACKGROUND OF THE INVENTION

The present invention relates to a method for making metal powder by means of atomizing molten metal that is poured from a vessel, using a fluid as an atomizing agent.

Various methods and apparatus have been suggested for atomizing molten metal, using highly pressurized air, nitrogen, argon or water as atomizing agent, and directing such atomizing fluid as a jet against a stream of molten metal. The jet is ejected, for example, from an annular nozzle or in flat sheets. The molten metal pours from a tundish, which is disposed above the nozzle unit, in a rather thin stream. This stream is exposed to the jet of atomizing fluid, usually in a particular level. If the nozzle unit has annular configuration, the molten metal pours through the central aperture of the unit, and a conical jet sheet with apex in the stream of molten metal hits the metal and breaks the stream up into a multitude of fine droplets. These droplets solidify rather quickly and are, for example, quenched in a water filled tank into which they drop. In the case of using flat jet sheets, the nozzle unit provides two such intersecting sheets with V-shaped configuration in cross section.

Equipment for practicing these known methods have the drawback that in some cases the resulting powder is not at all uniform. Particles formed in or near the center axis of the stream of pouring metal are relatively large resulting in a rather coarse powder. Particles formed from droplets near the periphery of the stream are considerably finer. The grain size is, thus, highly variable.

The droplets which become the powder particles are actually cast or thrown virtually down by operation of the downward directed component of the atomizing jet as acting on the stream from all sides. Therefore, in the case of making metal powder without oxygen content, large containers are used for permitting the droplets to solidify along a rather long path of free fall in an atmosphere of an inert gas. This is necessary to prevent caking or sintering of the droplets in the container bottom. Also, the diameter of the poured metal stream must be small, in absolute terms as well as in relation to the diameter of the opening in the nozzle unit through which the metal stream pours. This is absolutely necessary, because it must be avoided that metal drops touch the relatively cold wall of the nozzle unit, which may provide some welding action. Also, the metal must not adhere to the nozzle proper and clog same, due to rapid solidification. For example, an annular nozzle unit may have a central opening of about 70 mm. In such a case, the diameter for the stream of molten metal should not exceed 15 mm. Accordingly, the powder production rate is quite limited.

DESCRIPTION OF THE INVENTION

It is an object of the present invention to avoid the drawbacks and limitations outlined above. In accordance with the principle feature of the invention, the stream of molten metal is to have hollow configuration, preferably circular-annular configuration in cross section. Thus, in the preferred form of practicing the invention, the ladle or tundish from which the molten metal is to be poured, should have an annular outlet to produce a hollow string-like stream. Preferably, the molten metal runs as a film in a sheath-like flow over and along the surface of a mandrel serving as a guide for this tubular stream.

The hollow stream of molten metal is preferably atomized from the inside. Thus, the stream is atomized progressively from the inside towards the outside. Alternatively, the metal is atomized from the outside through an annular nozzle. In this case, gas is used to contain the stream; for example, (but not necessarily) the same gas that serves as atomizing agent, is fed to the interior of the hollow stream. The pressure of the sustaining gas is maintained sufficiently high so that the hollow stream is not constricted or pinched off in the atomizing region when impacted from the outside.

It was found advisable in cases to provide a series of atomizing regions, for example, by using another atomizing jet which breaks up further the initially produced droplets or redirects them, or both. The same or a different fluid can be used here in the secondary jet. This feature is particularly useful for extending the length of the travel path of a droplet before hitting the bottom. The second jet may, for example, send the droplets on a parabolic path so that it is well solidified when finally dropping on the heap of collected powder particles.

In summary, the invention offers the following advantages over atomization with a non-hollow stream:

1. A hollow stream, when atomized from the inside can be atomized at maximum speed of the atomizing agent, if the atomizing jet hits right where the hollow stream drops off a mandrel.
2. Even if the “wall thickness” of the hollow stream is quite thin, the amount of powder produced per unit time is considerably larger.
3. The powder quality is enhanced as the grain size is more uniform and finer, i.e. the production of coarse particles is actually inhibited.
4. The amount of atomizing agent needed for similar amounts of powder is considerably smaller.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention, it is believed that the invention, the objects and features of the invention and further objects, features and advantages thereof will be better understood from the following description taken in connection with the accompanying drawings in which:

FIGS. 1 through 4 each show longitudinal section views through closed-container equipment for atomizing molten metal in accordance with the preferred embodiment of the invention; and
FIG. 5 illustrates atomizing equipment in an open container.

DESCRIPTION OF THE DRAWINGS

Proceeding now to the detailed description of the drawings, we turn first to features which are common throughout. The molten metal 2 is contained in a tundish 1. Molten metal may be poured into tundish 1 from a ladle or the like, to replenish the supply. Except in FIG. 5, the tundish 1 is sealingly mounted to the top of a closed atomizing vessel, or container 7 in FIG. 1, '7' in FIG. 2, '7'' in FIG. 3 and '7'' in FIG. 4. The several closed containers are provided with outlets 14 and 15 to discharge excess atomizing fluid.

Common to FIGS. 1, 3 and 4 is a hollow mandrel 4 which is particularly mounted to traverse the bottom opening of tundish 1, forming an annular opening 41.
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therewith. Accordingly, molten metal 2 does not just pour from tundish 1 but runs as a film or sheath 3 along the outer surface of mandrel 4. The hollow stream as defined by film 3 of molten metal has annular configuration.

In accordance with FIGS. 1 and 4, atomizing fluid is fed to the upper part of hollow mandrel 4 by means of a suitable conduit 8. Hollow mandrel 4 by itself is open at the bottom, but a plunger 5 is provided for partially closing the mandrel. The plunger is provided with a curved internal contour, coacting with a curved bottom configuration of mandrel 4 to establish an annular nozzle from which atomizing fluid is ejected with strong radially outwardly directed component of jet flow. That annular, outwardly directed jet hits immediately the molten metal film 3 as it runs down along the outer surface of the mandrel 4, so that the metal is atomized immediately at the nozzle exit, in a region denoted with reference numeral 6.

The plunger 5 can be vertically adjusted so that the nozzle gap is adjusted therewith. The curved contour of plunger 5 and of the lower end of mandrel 4 determines the direction in which the metal drops fly when produced. When the metal is atomized in a closed container, the curvature of the nozzle may even be selected so that the molten drops fly with an upward component of movement. For open container atomization with pressurized water as atomizing fluid, the atomizing jet should be directed almost straight down.

The invention comprises a disposition to project towards tundish 1 from below and holding mandrel 9 which projects to some extent into the tundish. The mandrel 9 has somewhat conical configuration which provides also here for an annular gap flow passage with the tundish opening. An annular nozzle is established between the top of the tubular element 24 and the mandrel 9, particularly where the film 3 of molten metal runs off mandrel 9. The atomizing jet is directed straight outwardly blowing the resulting droplets in an almost horizontal direction. A conduit 8 leads into the tube 24 from below for feeding pressurized fluid into the tube 24 for discharge through the nozzle gap between elements 9 and 24. Container 7" is provided with a slanted bottom.

FIG. 3 illustrates a hollow mandrel 4 which is open at the bottom. The mandrel connects to a conduit 12 for connection to a source of pressure fluid for maintaining the tubular configuration of the metal film 3 as it runs off the mandrel. A relatively large annular nozzle unit 10 of conventional construction is disposed underneath the mandrel inside of vessel or container 7".

The hollow stream of molten metal is atomized through conical inwardly directed jet, but the pressure inside of the hollow stream prevents inward evasion of the molten metal on impact by the high speed atomizing agent. The conduit 8' for the pressurized atomizing fluid connects to the nozzle unit 10, possibly at different points along its circumference to obtain a uniform conical jet sheet configuration. The atomizing and hollow stream sustaining fluid may be the same, but, of course, the atomizing fluid has considerably higher pressure.

The mandrel portion and gap control for the atomizing jet in FIG. 4 was already explained above with reference to FIG. 1. There is now provided a duplicate mandrel 4' with plunger 5' acting from below, and providing an upwardly and outwardly directed jet flow, impacting on the conical configuration of the stream of atomized metal droplets as leaving region 6. This way, the droplets are further broken up to obtain a still finer powder. Moreover, the fine droplets are additionally blown in an upward direction, so as to extend the length of the flying path of each droplet. The closed container 7" is shown in double-wall configuration with a coolant 11, for example water, between. This variety of apparatus is particularly suited for atomizing metal into a very fine powder in an inert gas atmosphere, which is the same gas that is used as atomizing agent.

As stated above, the atomizing apparatus as shown in FIG. 5 is not encased. The mandrel 44, used here, has edge 13 from which the film 3 separates upon flowing down, continuing in free fall from the edge. Thus, the hollow metal stream enters as free fall in the atomizing zone. The metal droplets resulting from atomization drop into a water filled quenching tank.

The invention comprises embodiments described above but all changes and modifications thereof not constituting departures from the spirit and scope of the invention are intended to be included.

We claim:

1. In a method for producing metal powder by atomizing molten metal upon impact by a pressurized atomizing fluid and permitting resulting droplets to cool and to solidify, the improvement comprising:
   a. causing said molten metal to flow as a downflowing film over the outer surface of a hollow mandrel and leaving the lower end of said mandrel as an annular stream; and
   b. directing said pressurized fluid through said mandrel and as radially outward jet flow from the lower end of said mandrel to impinge upon and atomize the surrounding annular stream of molten metal into droplets and to displace said droplets in radial outward directions from said mandrel.

2. In a method as in claim 1, including the step of providing an additional flow of atomizing fluid and directing same towards the flow of droplets as atomized by pressurized fluid from the inside to break up the droplets further, so as to obtain a still finer powder.

3. In a method as in claim 2, the additional atomizing flow directed for redirecting the droplets.

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