SOME ASPECTS OF THE METAL POWDERS PRODUCTION FOR THE MACHINERY PARTS

Riskulov Alimjon Akhmadjanovich
DSc, Prof. of the Materials Science and Mechanical Engineering Department, Tashkent State Transport University
Alimukhamedov Shavkat Pirmukhamedovich
DSc, Prof. of the Materials Science and Mechanical Engineering Department, Tashkent State Transport University
Tursunov Nodirjon Kayumjonovich
Ph.D., Dr., Head of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University

Yuldasheva Gulnora Buranovna
PhD, Dr. of the Materials Science and Mechanical Engineering Department, Tashkent State Transport University
Mamaev Sherali Ibroximovich
Senior lecturer, of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University
Nafasov Jasurbek Himmat ugli
Senior lecturer of the Department of Materials Science and Mechanical Engineering, Tashkent State Transport University

Abstract

Powder metallurgy is a rapidly developing industry that produces powders from metals and other inorganic materials and sintered articles thereof. The use of powder metals, alloys and refractory compounds has begun in ancient times.

Even then, powders of gold, copper and bronze were used for decorative purposes in the manufacture of ceramics and as components of paints in painting.

Traditional technological process of powder metallurgy includes the following steps: obtaining of powders, molding of blanks thereof, sintering and final processing (sizing, crimping, heat treatment, etc.) of article. Its improvement has led to the establishment of specific operations which include gasostatic pressing of powders, their molding by injection into a matrix, powders obtaining in conditions of ultrafast (10^6-10^{7}°C/s) cooling and other operations that extend the capabilities of powder metallurgy.

Keywords: Metallic compounds; atomization of melt; dispersion of melts; ultrasonic dispersion; vortex mills; metal cutting; grinding by crushing, milling and attrition.

1. Introduction

Production of metal powders is the first process operation in powder metallurgy. Methods of production of metal powders are divided into mechanical, and physical and chemical (Figure 1). During the mechanical crushing, the chemical composition of basic material is practically unchanged. Physical and chemical methods cause significant changes in the chemical composition of powder particles in comparison with basic material.

Mechanical methods of powders production.

Mechanical methods include grinding of solid materials and dispersion of molten metals.

Mechanical *grinding of solid materials* is widespread in powder metallurgy. This method can help to transform practically any metal or alloy into a powder.

Grinding is reduction of initial size of solid particles by means of their destruction (crushing) by external forces which overcome interaction forces of atoms or molecules in the material. Crushing is useful for manufacturing of powders of brittle metals and alloys (silicon, beryllium, antimony, chromium, manganese, ferro-alloys, aluminum-magnesium alloys, etc.).

Crushing of viscous plastic metals (zinc, copper, aluminum, etc.) is difficult, since their particles are mainly deformed and do not collapse.

Energy expended on crushing of solid bodies is spent on elastic and plastic deformation of particles, the heat release and formation of new surfaces, that is the ultimate goal of grinding. At the moment of destruction the stress in deformable particle exceeds the tensile strength of material, elastic deformation is replaced by rupture strain and there is a division of particles into fragments.

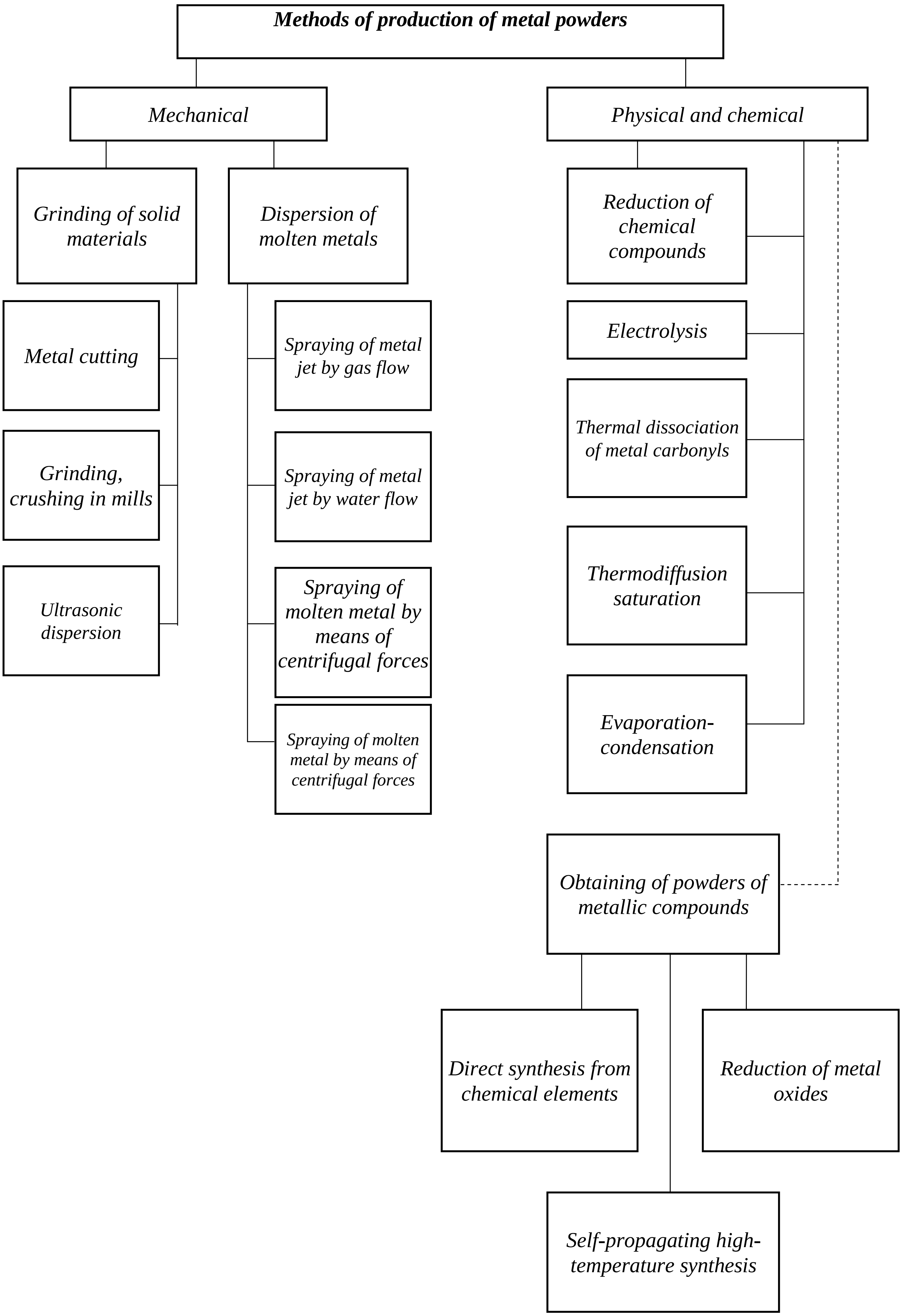

Figure 1. Classification of main methods of metal powders production

2. Methods

According to the theory of crushing suggested by Academician P.A. Rebinder, work A expended for grinding of solid bodies in general case is the sum of two energies:

$$A = E_D + E_S \quad (1)$$

where $E_D = K\Delta V$ and $E_S = \sigma\Delta S$.

Here E_D - energy of deformation; K - recoverable strain and plastic deformation work per unit volume of solid body; ΔV - volume of the body exposed to deformation; E_S - energy expended on the formation of new interfaces in the destruction of solid body; σ - specific surface energy; ΔS - increment of the surface during grinding.

If the particles obtained by crushing are large enough, area of resulting surface is small, therefore $\sigma\Delta S << K\Delta V$ and power consumption on crushing is approximately proportional to volume of the body being destroyed. Under fine grinding, surface of newly formed particles is very large and $\sigma\Delta S >> K\Delta V$, therefore power consumption on grinding is approximately proportional to surface being formed. Dispersing is fine grinding of a body in environment. Unfortunately, the amount of useful work of mechanical dispersion of solid bodies is very small, because a significant part of useful energy of grinding device is spent on the deformation of body being grinded and is evolved into heat.

The most widely used mechanical methods of powders production are: 1) metal cutting with transformation of the metal into small chips or filings; 2) grinding of metal wastes by means of ball, hammer, jet and other mills; 3) ultrasonic dispersion.

Metal cutting is mainly used to obtain metal powders which are active to oxygen, especially in state of high dispersion. For example, magnesium powder is obtained by scratching of solid block of magnesium (pig magnesium) with steel brushes on so-called "Kratz machines" or milling machines.

Grinding by crushing, milling and attrition can be considered both as independent method of transformation of material into powder and as additional operation in other methods of powders obtaining. Choice of equipment and its operation mode is determined by properties and initial state of grinding material and by desired shape and size of particles.

The simplest device for grinding is a *ball rotating mill*. This is steel cylindrical drum which has milling agents (steel or hard-metal balls) inside. When the drum rotates they go up the wall by centrifugal force and then roll down. Crushing of material occurs as a result of attrition and impact action of balls. For rotating ball mills degree of metal grinding (ratio of average particle size of powder before and after grinding) is 50-100. Duration of milling varies from several hours to several days.

Ball vibratory mills promote faster and finer crushing of material. Powders of titanium, tungsten, silicon, chromium, vanadium, boron carbides, and fine powders of aluminum and bronze are obtained by vibratory grinding. Vibratory mill body performs circular oscillations with amplitude of 2–4 mm and trajectory of any point of body lies on plane perpendicular to axis of vibrator. As a result, particles of material being grinded in all areas of mill are subjected to impact, compressive and shearing forces of variable quantity. Main indices of vibro-milling such as volume filling factor of mill with grinding bodies and material being grinded, the ratio between them by weight, kind of milling ("dry" or "wet") are usually set experimentally taking into account properties of material being grinded and required grinding fineness.

Grinding in *vortex mills* occurs at the expense of collision of solid particles transported by two oppositely directed vortex gas streams. The latter are created in processing chamber of mill by two propellers which are arranged opposite one another and rotate in opposite directions with high (up to 3000 r/min) speed.

Vortex grinding is used for obtaining of thin and pyrophoric (capable to self-inflammability in air) powders, for example, based on iron. Inert gas is added by oxygen (5%) for creation of protective oxide films on newly formed surfaces of powder particles. It is introduced instead of oxygen into working chamber in order to prevent self-inflammability. *Vortex jet mills* are more effective.

Ultrafine (to 1-5 microns) grinding of material in which is performed by compressed gas jets or by superheated steam flowing into working chamber with sonic or even supersonic speed.

Ultrasonic dispersion of materials is carried out in liquids (water, alcohol, acetone, etc.). Grinding mechanism is wedge effect force on particles of cavitation impacts. In liquid medium vacuum generated by sound wave causes cavitation, i.e. the formation of bubbles or cavities filled with gas, steam, or a mixture thereof. Cavities grow rapidly and then instantly slam (close up) in the compression phase of ultrasonic wave. At the time of slam, impact waves are generated, they create in liquids pressure up to 1000 MPa which is enough for mechanical destruction of particles of grinded materials. Powders obtained in this manner are characterized by high chemical purity.

Dispersion of melts is a group of the most widespread industrial methods of metal powders and alloys producing for needs of powder metallurgy.

Wide application of dispersion of metals in liquid state is caused by three factors: 1) sharp intensification of heat and mass transfer with decreasing amounts of dispersible materials; 2) significant reduction of energy of dispersion; 3) possibility of obtaining final product in the form and state, suitable for subsequent use in powder metallurgy.

3. Results and Discussion

Let us consider some theoretical aspects of melts dispersion.

Liquid jet flowing spontaneously from circular hole strives to preserve the equilibrium cylindrical shape.

Resulting from the effect of small perturbations generated by channel imperfection (wall roughness, deviation from ideal shape of hole, etc.), flowing jet acquires more deformed shape. Each of small perturbations generates pulsation in liquid, which creates conditions for wave oscillations emergence. Latter causes division of jet into drops. Distance from hole where wave character of moving fluid in jet starts to appear depends on outflow velocity of jet (Figure 2, *a* and *b*).

At high speed of outflow (v>100 m/s) process of disintegration of jet under the influence of wave movement of liquid is transformed into process of atomization at which zone of dispersion of liquid is shifted to nozzle exit section.

Outflow is accompanied by formation of conical plume consisting of droplets of liquid (Figure 2, *c*).

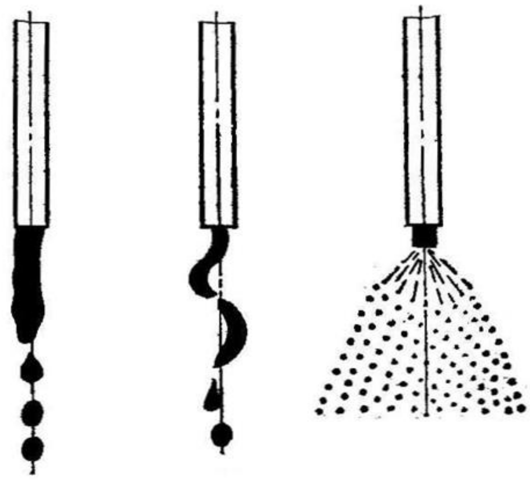

Figure 2. Scheme of jet dispersion depending on speed of its outflow: *a* - at the expense of axisymmetric oscillations at speed of outflow below 25 m/s; *b* - at the expense of axis-asymmetrical oscillations at speed of outflow between 25 m/s and 100 m/s; *c* - jet atomization at speed of outflow of 100 m/s

Atomization of melt with water is one of the major industrial methods of manufacturing of powders of iron, alloyed steels and alloys. Due to higher density of water in comparison with gas, its flow is characterized by high values of impulse ($M = mv$) and kinetic energy ($E = mv^2/2$). High speed of water droplets flow is retained at much greater distances from nozzle exit section (to 200 - 250 mm) than gas flows do. This enables changing of mutual position of melt and water jets, this facilitates the design of devices for atomization.

When contacting of water jet with molten metal process of intensive evaporation is inevitable. For this reason, dispersion of melt jet is actually carried out not with water, but with superheated pressurized steam. Formation of steam jacket while spraying of melt with water causes significant change in thermal process parameters. Cooling rate of atomized drops decreases sharply because of deterioration of heat transfer through steam in comparison with heat transfer through water.

Scheme of devices for atomization of melt jet with water are similar to schemes used for atomization with gases. In modern atomization devices melt jet is crushed by jets of water directed from two or four sides at angles close to 60–70^o. Water consumption reaches several tens of liters per 1 kg of molten metal.

4. Conclusion

In comparison with mechanical physical and chemical methods they are more universal therefore tough requirements for metal powders in some industries can be satisfied by using these methods.

Direct synthesis from elements, reduction processes, electrolysis of molten salts and self-propagating high-temperature synthesis (SHS) are used *to obtain powders of metallic compounds*. Metallike compounds have, as a rule, high hardness and melting point and have complicated connections which combine metallic, covalent and ionic constituents. These are hydrides, carbides, nitrides, borides and silicides of transition metals, silicon and boron carbides, boron, aluminum and silicon nitrides.

Direct synthesis from elements is the simplest and most widespread method of obtaining powders of almost all metallike compounds. The homogeneous on phase and chemical composition powders with average particle size of 20 – 30 microns can be obtained by means of the direct synthesis technology carried out in the temperature range of 1100 – 1500°C for several hours.

References:

1. Riskulov, A. A., Yuldasheva, G. B., Kh, N., & Toirov, O. T. (2022). Derivation processes of fluorine-containing wear inhibitors of metal-polymer systems. *Web of Scientist: International Scientific Research Journal*, *3*(5), 1652-1660.
2. Riskulov, A. A., Yuldasheva, G. B., & Toirov, O. T. (2022). Features of fluorocomposites obtaining for wearing parts of machine-building purpose. *Web of Scientist: International Scientific Research Journal*, *3*(5), 1670-1679.
3. Тоиров, О. Т., Кучкоров, Л. А., & Валиева, Д. Ш. (2021). Влияние режима термической обработки на микроструктуру стали Гадфильда. *Scientific progress*, *2*(2), 1202-1205.
4. Kayumjonovich, T. N., & Zokirov, R. V. (2022). The metal refining problem and technical solutions for the active slag formation in induction furnaces. *Web of Scientist: International Scientific Research Journal*, *3*(5), 1755-1760.
5. Тен, Э. Б., & Тоиров, О. Т. (2020). Оптимизация литиковой системы для отливки «Рама боковая» с помощью компьютерного моделирования. In *Прогрессивные литейные технологии* (pp. 57-63).
6. Азимов, Ё. Х., Рахимов, У. Т., Турсунов, Н. К., & Тоиров, О. Т. (2022). Исследование влияние катионов солей на реологический статус геллановой камеди до гелеобразования. *Oriental renaissance: Innovative, educational, natural and social sciences*, *2*(Special Issue 4-2), 1010-1017.
7. Тоиров, О. Т. У., Турсунов, Н. К., & Кучкоров, Л. А. У. (2022). Совершенствование технологии внепечной обработки стали с целью повышения ее механических свойств. *Universum: технические науки*, (4-2 (97)), 65-68.
8. Кучкоров, Л. А., & Турсунов, Н. К. (2021). Исследование состава формовочных и стержневых смесей для повышения механических свойств. *Scientific progress*, *2*(5), 350-356.

9. Kayumjonovich, T. N. (2022). Research and improvement of steel refining modes in induction furnaces in order to improve the products quality. *Web of Scientist: International Scientific Research Journal*, *3*(5), 1713-1719.
10. Kayumjonovich, T. N. (2022). Development of a method for selecting the compositions of molding sands for critical parts of the rolling stock. *Web of Scientist: International Scientific Research Journal*, *3*(5), 1840-1847.
11. Турсунов, Н. К., Семин, А. Е., & Котельников, Г. И. (2017). Кинетические особенности процесса десульфурации при выплавке стали в индукционной тигельной печи. *Черные металлы*, (5), 23-29.
12. Турсунов, Н. К., Семин, А. Е., & Санокулов, Э. А. (2017). Исследование процессов дефосфорации и десульфурации при выплавке стали 20ГЛ в индукционной тигельной печи с дальнейшей обработкой в ковше с использованием редкоземельных металлов. *Черные металлы*, (1), 33-40.
13. Турсунов, Н. К., Санокулов, Э. А., & Семин, А. Е. (2016). Исследование процесса десульфурации конструкционной стали с использованием твердых шлаковых смесей и РЗМ. *Черные металлы*, (4), 32-37.
14. Рахимов, У. Т., Турсунов, Н. К., Кучкоров, Л. А., & Кенжаев, С. Н. (2021). Изучение влияния цинка Zn на размер зерна и коррозионную стойкость сплавов системы Mg-Nd-Y-Zr. *Scientific progress*, *2*(2), 1488-1490.
15. Tursunov, N. K., Semin, A. E., & Sanokulov, E. A. (2017). Study of dephosphoration and desulphurization processes in the smelting of 20GL steel in the induction crucible furnace with consequent ladle treatment using rare earth metals. *Chernye Metally*, *1*, 33-40.
16. Семин, А. Е., Турсунов, Н. К., & Косырев, К. Л. (2017). Инновационное производство высоколегированной стали и сплавов. Теория и технология выплавки стали в индукционных печах.
17. Tursunov, N. K., Semin, A. E., & Sanokulov, E. A. (2017). Research of dephosphorization and desulfurization processes in smelting of 20GL steel in an induction crucible furnace with further processing in a ladle using rare earth metals. *Chern. Met*, *1*, 33-40.
18. Tursunov, N. K., & Ruzmetov, Y. O. (2018). Theoretical and experimental analysis of the process of defosphoration of steel used for parts of the mobile composition of railway transport. *Journal of Tashkent Institute of Railway Engineers*, *14*(2), 60-68.
19. Нурметов, Х. И., Турсунов, Н. К., Туракулов, М. Р., & Рахимов, У. Т. (2021). Усовершенствование материала конструкции корпуса автомобильной тормозной камеры. *Scientific progress*, *2*(2), 1480-1484.
20. Турсунов, Н. К., Уразбаев, Т. Т., & Турсунов, Т. М. (2022). Методика расчета комплексного раскисления стали марки 20гл с алюминием и кальцием. *Universum: технические науки*, (2-2 (95)), 20-25.
21. Kayumjonovich, T. N. (2022). The problem of metal refining and technical solutions for the formation of active slag in induction furnaces. *Web of Scientist: International Scientific Research Journal*, *3*(5), 1996-2001.
22. Tursunov, N. K., Toirov, O. T., Nurmetov, K. I., Azimov, S. J., & Qo‘Chqorov, L. A. (2022). Development of innovative technology of the high-

quality steel production for the railway rolling stock cast parts. *Oriental renaissance: Innovative, educational, natural and social sciences*, *2*(Special Issue 4-2), 992-997.
23. Тен, Э. Б., & Тоиров, О. Т. (2021). Оптимизация литниковой системы для отливки. Литейное производство, (10), 17-19.
24. Тоиров, О. Т., Кучкоров, Л. А., & Валиева, Д. Ш. (2021). Влияние режима термической обработки на микроструктуру стали гадфильда. Scientific progress, 2(2), 1202-1205.
25. Рисқулов, А. А., Юлдашева, Г. Б., Турсунов, Н. Қ., & Нурметов, Х. И. (2022). Таълимда замонавий инновацион технологияларни қўллаш–юксак малака эгаси бўлиш демакдир. Academic research in educational sciences, 3(TSTU Conference 1), 146-150.