FACTORS INFLUENCING THE MACHINABILITY OF SINTERED STEELS

E. Alizadeh1

The machinability of powder metallurgy materials is considered to be poor. The main factors that deteriorate the machining of PM parts are introduced in this work. They are those which participate in different ranges and modes in the formation of a sintered body with required mechanical and other characteristics. The effect of base iron powders, alloying systems, and alloying elements, as well as the effect of processing routes, especially solid-state sintering, are mentioned. The characteristic heterogeneous microstructures are presented. The effect of porosity in terms of interrupted and deformation cutting theories is discussed and demonstrated. The main measures to improve machinability of PM materials are described.

Keywords: powder metallurgy, sintered steels, microstructure, machinability, machining aids.

INTRODUCTION

Machinability is not a property of materials, but is a mode of the material during cutting. Machinability is in reality a manifestation of the interaction of work piece and tool under the specific effect of power. It is a term that is difficult to define and can be measured by a number of parameters to indicate, qualitatively and quantitatively, the ability of a material to be cut. Machining is in its variety a processing method for an oriented destructive failure of metallic bodies to achieve a designed shape, size, and surface finish quality at acceptable costs.

“Machinability Index” and “Machinability Rating” are terms used to give a relative measure of machinability. Historically, quantitative measures have been based on one or more criteria such as the number of parts machined until tool failure, the maximum of cutting speed achieved, torque and power requirements, etc. However, even these entities remain partially undefined and are not standardized [1]. The cutting operations are well understood in wrought component machining, but when they are applied to the machining of PM products certain problems can arise [2].

In powder metallurgy (PM) parts production, there is a large number of shapes that are difficult or impossible to produce by pressing without machining, e.g., undercuts, slots, bevels, blind holes, threads, and cross-holes and re-entrants normal to the pressing direction. They require secondary finishing, e.g., by drilling and turning also for high dimensional accuracy and surface finish quality [3, 4]. At present, about 40–50% of PM parts needs secondary operation-machining. Machining in powder metallurgy should be regarded also as a special processing method which enlarges the application area of PM parts to more sophisticated ones which are presently the domain for conventional machining processing routes from wrought steels. Between them, a very important and large group forms parts produced from high strength, high fatigue strength, and high wear resistance steels.

1Guilan University, Faculty of Science, Department of Chemistry, P.O. Box: U Rasht, Iran.

The machinability of PM materials is regarded generally as poor as compared to machining of wrought steels. It follows from it that the tool life is shorter in machining of a PM material and therefore the process is less cost effective. Since general comparable data for this statement are missing, it can be therefore stated that a unit (mass, volume) amount of a PM material removed by cutting with one cutting tool edge up to the total tool failure is more expensive as compared to machining of wrought steel, not only with comparable mechanical properties. On the other hand, it must however be considered that the amount of the material removed in the form of chips in PM parts machining is 10–15% maximum. The waste through chips in the production of structural parts by machining from wrought steels is typically 40–60%. This should be a very important economical and environmental advantage for PM and improve the machinability of PM parts.

The machinability of PM steel is influenced by more factors than the machinability of wrought steel of equal mechanical properties, mainly by different base microstructure in what is the concentrated effect of all factors taking part in the formation of a sintered metal body as compared to those which are involved in wrought steel characteristics.

Measures to improve the machinability of PM steels are therefore the objective of systematic research efforts and of practical experiences in the field [5].

They are oriented mainly on the modification of the properties of the work piece by additions of free-machining additives, further of some processing variables and of the cutting tool material and tool geometry. The main causes of the poor machinability of PM steels are not sufficiently defined and therefore the investigation is made always in a broad range oriented more on practical machining indices.

The main factors are introduced in this work: a) that cause the deterioration of machinability, and b) those that are used and investigated for improving the machinability of PM materials, namely in drilling and turning as representative of cutting methods with geometrically defined cutting edges. This knowledge is based on the data presented in [6].

**STARTING FACTORS AFFECTING PM MACHINABILITY**

A simplified view makes it possible to say that all physical, chemical, and technological properties of starting powder materials used and of processing variables and characteristics that can be defined and measured are factors which are involved in the formation of a solid body in sintering in solid state or, in the presence of liquid phase, are those which contribute, each of them in a specific manner, to the poor machinability of PM materials. The following data are always considered in relation to machining of final sintered products.

**Effect of Materials and Processing Routes.** The main powders and mixtures used for manufacturing PM materials, which are characterized by specific properties determining the final properties of a sintered product, are: (a) iron powders; (b) sponge iron powders produced by reduction of pure iron ore; (c) water atomized powders; and (d) prealloyed (water atomized, some vacuum annealed) powders. These powders form three groups according to alloying, i.e., Ni–Mo–(Mn), Cr–Mo–(V), and Mo powders with their specific chemical and physical properties.

The final characteristic properties of iron powders are effected by the properties of raw materials used for their production (ore, scrap), and by the production and preparation methods. The highest possible chemical purity of as-delivered powders also in terms of machinability is required, i.e., <0.05% carbon content, <(0.1–0.2)% oxygen content, and minimal possible content of the elements coming from raw materials used (S, Si, Mn). Nonmetallic inclusions in sintered materials coming from ore or slag are often mentioned in the literature as impurities deteriorating the machinability of sintered steels. The amount of nonmetallic inclusions is however not given as a characteristic of iron base powder.

The effect of different physical and technological properties of starting sponge and atomized iron powders is evidenced by different as-sintered properties which are, for example, the hardness in the range of 55 to 72 HV and the tensile strength of 200 to 240 MPa at the density of 6.7 to 7.1 g/cm³ [7]. This effect is shown also on different properties, e.g., of Distaloy SA and AB steels based on sponge and atomized iron powders. In terms of machinability, it was also stated that the materials based on sponge iron powder exhibit higher machinability in turning and those based on atomized iron powder in drilling [6, 8]. It means that the starting differences in chemical