3 Forming

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3.1 Introduction

In many cases the method of giving shape to a mass of powder is decisive for the competitiveness of the process. Opposite to conventional metallurgy where a shape is achieved by melting, casting, hot and cold working and subsequent machining, in powder forming a vast number of methods has evolved, many of them as problem solvers for special applications or niche processes which are operated worldwide only in a single location.

The way of forming depends mostly on whether the powder develops green strength under compressive stresses. Powders with green strength after compaction do not need external support for further handling, powders without green strength must be filled in containers for consolidation or in some cases can be kept in shape by binders. There are, however, no dogmatic border lines between the different possibilities, the purpose dictates the method of forming.

The product of the shaping step within the production sequence can be a net shape green part, a near-net shape blank which affords secondary operations after consolidation, a semifinished product or a billet for hot or cold working. The masses handled in forming processes can range from several mg up to 10 Mg, extending over ten orders of magnitude.

3.2 Uniaxial compaction in rigid dies

3.2.1 Die compaction of powders with green strength

Of all powder metallurgical forming techniques die compaction is by far the most economical and important method. From powder shipments and average part weights it can be estimated that worldwide some $10^3$ components are die compacted from metallic materials each year. The powders for die compaction can be irregular, to provide for mechanical interlocking of adjacent particles on compaction, or they can contain soft organic binders in large percentages that bond the particles together. Powders without a binder, which are used for mass production, need a certain amount of lubricant which can be added in a blending operation in the form of microflake waxes, soaps, amides or mixtures of these; sometimes solid state lubricants are extended by an addition of small amounts of fatty acids. The total quantity of lubricants rarely exceeds 1 % by mass. In structural parts manufacturing, the majority of the powders processed are irregular in shape and have very low deformation resistance for best compressibility. Usually forming and consolidation are separate steps for die compacted components, there are however exceptions.

The terminology of the active parts of a typical compaction tool will be explained by means of Fig. 3.1. In a widely preferred type of press design the lower punch is fixed to the press frame and constitutes the reference level of the tool. The lower punch, core rod and die form the cavity which is filled with loose powder. The die is commonly designed as a single cylindrical shrink fitted hard and wear
resistant core in a medium strength steel shrink ring. For compaction the upper press ram moves the upper punch down reducing the height of the powder column roughly by a factor of 2 to 2.5. According to Fig. 3.2 a press cycle consists of the steps filling, compacting, ejection and removing the compact out of the press area. To this end a powder press is equipped with a so-called feeder or feed shoe to which the powder is normally supplied via a flexible hose. The feed shoe slides over the upper die face until the cavity is fully covered and gravity filled with the free flowing powder. For more uniform and reproducible fill, the feed shoe can be shaken back and forth once or several times. While approaching the cavity the feeder pushes the ejected compact of the previous cycle over the die platen out of the press. Instead of pushing the part away, it can also be picked up by a special device and placed on sintering plates or in trays.

In presses, where the lower punch is fixed to the press frame, ejection takes place by withdrawing the die over the lower punch until the compact has fully emerged flush with the die platen, Fig. 3.3a. In some more recent developments [89Bei, 96Dor, 96Kom, 96Lin] the die platen is the reference for all tool movements. To eject, the lower punch is lifted to the level of the die face, Fig 3.3b.

![Fig. 3.1. Tooling for a simple die compacted part.](image)

1: Stationary lower punch  
2: Core rod  
3: Die core  
4: Shrink ring  
5: Powder  
6: Upper punch  
7: Compact