

## CHAPTER 1

# Introduction\*

### 1.1 Basic Principles of Extrusion

THE EXTRUSION OF METALS, in which a billet, usually round, is pressed by a stem at high pressure through a tool of the desired shape, the die, to one or more lengths, first achieved its important position in the semi-finished product industry in the twentieth century. The process was used mainly for the production of bar, wire, tubes, and sections in aluminum alloys and copper alloys. However, stainless steel tubes, steel sections, and semi-finished products in other metals also are produced in small quantities by extrusion.

Figure 1.1 illustrates the two most important types of extrusion:

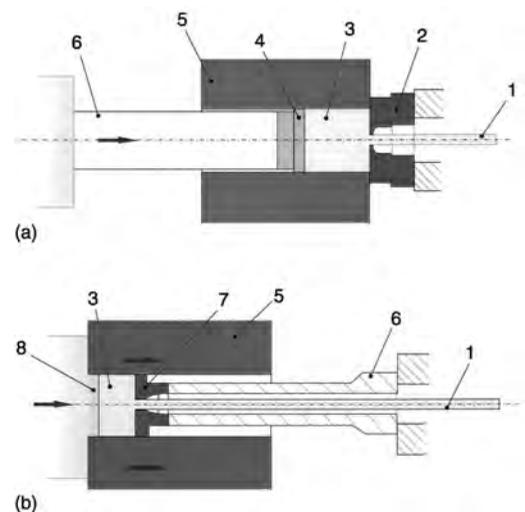
- In *direct extrusion*, a stem, usually with a pressure pad in front, pushes the billet in a stationary container through a tool of the desired shape, the die. Relative movement takes place between the billet and the container.
- In contrast, in *indirect extrusion*, the die is located in front of a hollow stem and pushed against the billet by the forward movement of the container closed at the back. There is, therefore, no relative movement between the billet and the container.

During extrusion, a compressive stress state is developed within the billet, which enables large deformations to be achieved with a low risk of cracking. The ratio of the billet cross-sectional area to that of the extruded section is known as the extrusion ratio. It usually falls in the range 10 to 100. In special cases—for example, brass wire—the extrusion ratio can be as high as 1000. However, this requires the material's being extruded to have a low flow stress

in addition to a high specific press pressure of up to  $1000 \text{ N/mm}^2$ . Extrusion is therefore normally carried out at a high temperature: aluminum alloys usually in the range 400 to 500 °C, copper alloys between 600 and 900 °C, and stainless steels and special materials up to 1250 °C.

Mention should also be made of the special processes of hydrostatic extrusion, the conform process, and cable sheathing also described in this book.

In **hydrostatic extrusion (Fig. 1.2)**, the billet is surrounded by a pressurized fluid. This has the advantage of negligible liquid friction between the billet and the container. The only friction that has to be taken into consideration is between the material and the die. Because the



**Fig. 1.1** Extrusion processes. (a) Direct extrusion. (b) Indirect extrusion. 1, extrusion; 2, die; 3, billet; 4, dummy block; 5, container; 6, stem; 7, dummy block with die; 8, sealing tool

\*Historic Development of Extrusion, Martin Bauser

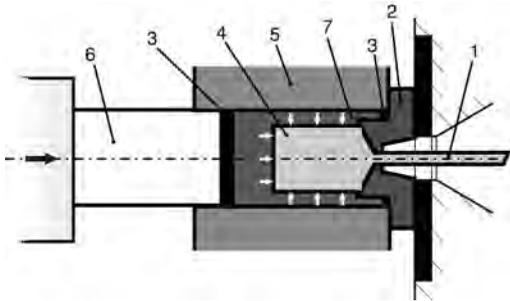
process is difficult to operate and the pressurized fluid can withstand only relatively low temperatures, which restricts the extrusion ratios that can be achieved, the process has only limited applications in spite of initial great hopes.

**In the conform process (Fig. 1.3),** a continuous feedstock is extruded through the die by a rotating friction wheel with a groove that is closed by a semicircular shoe. Small cross sections and relatively low deformation ratios are possible. Only a few applications are known.

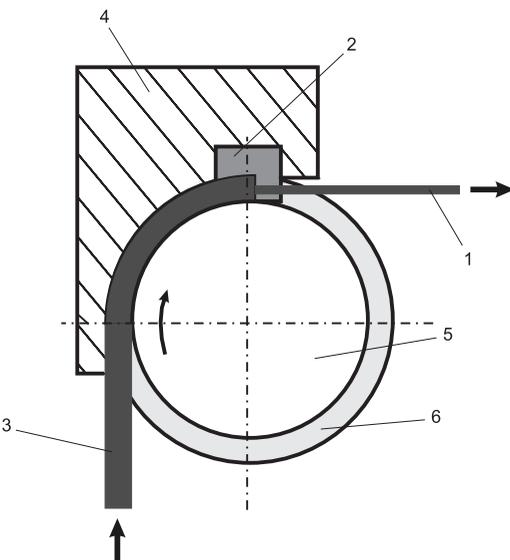
The standard processes, i.e., direct and indirect extrusion, have step by step reached high levels of productivity and quality combined with a simultaneous reduction in operating personnel associated with improvements in machine technology and upstream and downstream equip-

ment, modern control technology, and the optimization of tooling materials and tooling design.

Knowledge of the fundamental principles of metallurgy, as well as the basics of deformation technology, machinery, and tooling, is needed to understand the extrusion process. All these aspects are discussed in this book.



**Fig. 1.2** Hydrostatic extrusion. 1, extrusion; 2, die; 3, seal; 4, billet; 5, container; 6, stem; 7, hydrostatic medium



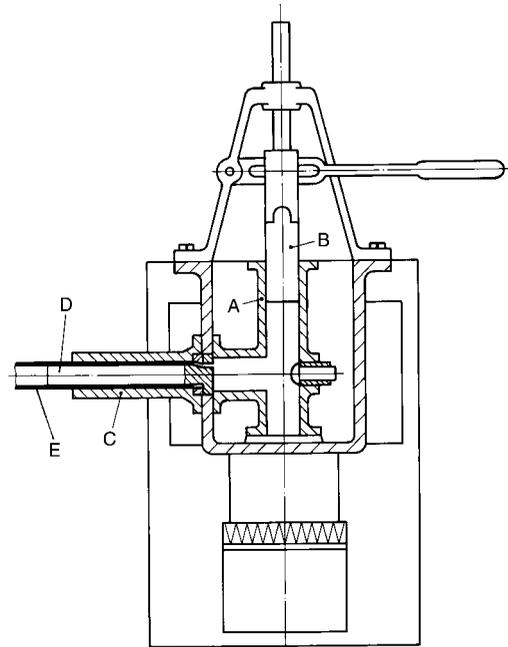
**Fig. 1.3** Conform process. 1, extrusion; 2, die; 3, feedstock; 4, shoe; 5, friction wheel; 6, groove

## Historic Development of Extrusion\*

Martin Bauser

Joseph Bramah described in a patent in 1797 a “press for the production of pipes of a specific diameter and length without joints in lead and other soft metals” (Fig. 1.4). Joseph Bramah used liquid lead forced from a melting vessel A

\*Historic Development of Extrusion, Martin Bauser



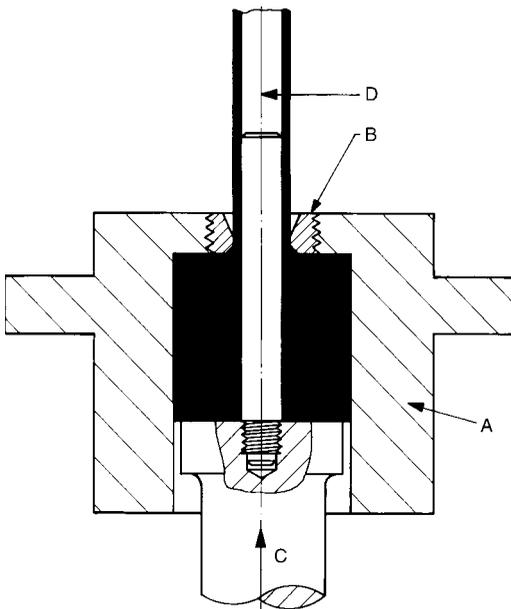
**Fig. 1.4** Bramah's lead piston press, 1797. A, melting chamber; B, piston; C, tube support; D, tube mandrel; E, extruded tube

by the piston B through a valve into the cylinder. The liquid material is then pushed by the piston as split metal streams through annularly located openings in the mandrel support so that the metal streams combine and solidify in the annular gap formed by the tube mandrel D and the tube support C to form a tube E.

Pure lead melts at 327 °C, and most of its alloys at an even lower temperature, so that this material can be formed with low loads even at 80 °C. Therefore, lead was the only important extruded material up to the end of the nineteenth century. Many of the important elements of the process used today were, however, developed during this period.

The first known design of a (vertical) hydraulic extrusion press for lead tube was developed by the Englishman Thomas Burr in 1820 (Fig. 1.5). It had a container A, an extrusion stem with a machined-in pressure pad, a threaded mandrel, and a replaceable die B.

England played a leading role in extrusion as well as in many engineering fields. Lead pipes were used there relatively early for water supply pipes. English inventions from the nineteenth century include the bridge die, the hydraulic accumulator, the gas-heated container, and the indirect extrusion process. Specific mention should be made of the invention of I. and C.



**Fig. 1.5** First hydraulic lead press (Th. Burr, 1820). A, container; B, die; C, extrusion stem with machined dummy block and threaded mandrel; D, extruded tube

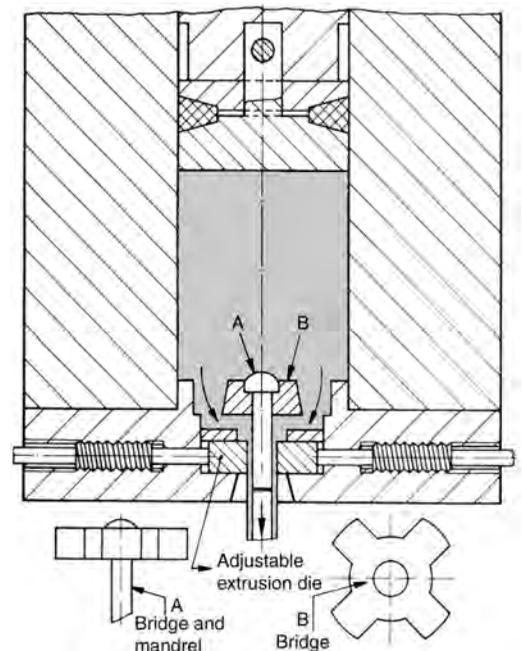
Hanson, who, as early as 1837, were producing lead tubes from a solid billet through a multipart bridge die with a replaceable fixed pressure pad (Fig. 1.6).

The first two-piece container heated with gas was developed by Hammon in 1867.

The start of electrification opened a new market for lead as a cable sheathing material. The first cable sheathing press was built by Borell in 1879 in which lead was extruded directly onto the cable core. The process was improved in 1882 by Werner von Siemens.

Alexander Dick, who lived in England, succeeded in developing from lead extrusion the processing of metals with higher melting points. He is therefore quite correctly considered to be the “father of extrusion.”

In 1894, Dick registered a patent for an extrusion press designed specifically for brass rod (Fig. 1.7) [Dic 94]. His idea was to cast liquid metal into the vertically orientated container and to let it solidify. After rotating the container into the horizontal position, the product was extruded from this initial heat through a replaceable die, F. Direct water pressure pushed the stem forwards. A pressure pad protected it from the billet heat and prevented back extrusion of the metal. The die and die holder, E, were sealed against the cross head by two wedges, D. These were



**Fig. 1.6** First bridge die by I. and C. Hanson (1837)

opened at the end of the extrusion process, and the die discard and pressure pad ejected using the stem (Fig. 1.8).

Because the one-piece container made from cast iron or steel tended to crack under the thermal stresses developed by the casting of the hot metal, a multipiece container was introduced in 1896. However, the individual cylinders were not prestressed but merely insulated from each other by powdered graphite and borax.

The time-consuming process copied from lead pipe extrusion of filling the container with liquid metal was soon replaced by the use of preheated cast billets. Alexander Dick described over a period of time many important details in numerous patents: the loose pressure pad, various mandrel designs for tubes, dies for multihole extrusion, and even a hollow section die. The three-piece bridge die patented by Alexander Dick in 1897 is shown in Fig. 1.9 [Dic 97]. The billet is divided into six streams that weld together in the shape forming aperture.

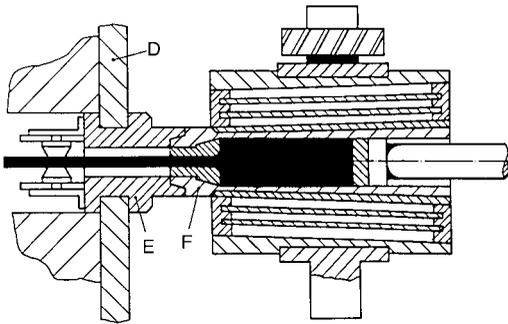
The manufacture of extrusion presses with press capacities of more than 7 MN enabled larger billets to be used, thus giving an economic

production. The water hydraulic extrusion press was powered by a pressurized water system consisting of pumps and accumulators. The hot billets were manually loaded into the container using tongs. Hand-operated valves were used to control the operating sequence of the extrusion press. The extruded products had to be handled manually with tongs.

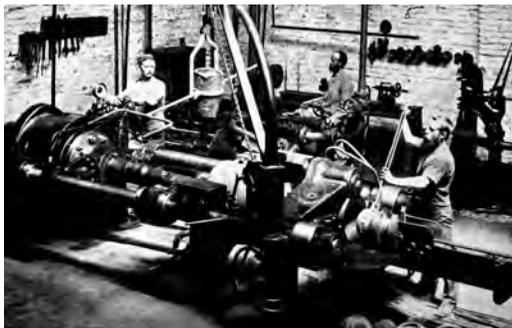
Rapid developments at the start of the twentieth century resulted in the extrusion process completely replacing the previously standard process for the production of bars, sections, and wire in copper alloys of section by rolling of cast billets. More than 200 extrusion presses, mostly for brass, had been built by 1918 (mainly by the German company Krupp-Gruson). However, even steel sections were being extruded by 1914.

Although it was possible to produce tubes on standard presses by the development of “floating mandrels,” which were a loose fit in the hollow billet and were heavily tapered toward the die, this was replaced—following a patent by Arnold Schwieger in 1903—by a piercing system located behind the main cylinder (Fig. 1.10).

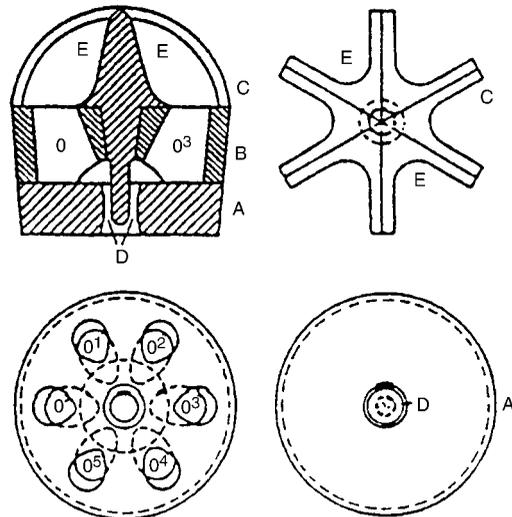
The mandrel holder passing through the main cylinder carries the mandrel at its tip, which can pierce the solid billet. This then forms the internal contour of the tube in the die. These presses, which can naturally also be used to extrude solid bars by removal of the mandrel, were built up to the 1950s. Then the internal piercer enabled the press length to be shortened and the alignment of the mandrel—to be improved (Fig. 1.11).



**Fig. 1.7** First brass extrusion press. D, wedges; E, die and die holder; F, replaceable die (A. Dick, 1894)

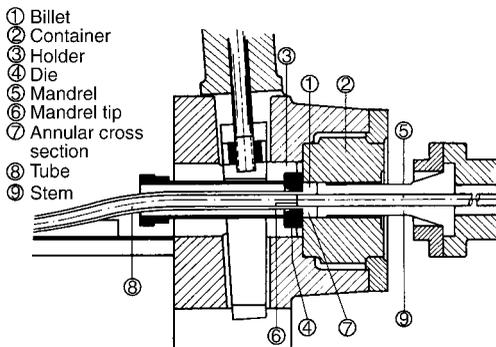


**Fig. 1.8** Hydraulic extrusion press (1895)



**Fig. 1.9** Bridge die by A. Dick (1897)

In the 1920s, experience showed that that the concentricity of internal and external tube walls was better on vertical hydraulic presses because of the favorable influence of gravity. The mandrel was rigidly screwed to the stem and pre-pierced billets used. In the 1950s, numerous vertical tube presses were built (by the companies Schloemann and Hydraulik) but now with independent mandrel movement and automatic operation for the production of copper and brass tubes. The manufacture of vertical presses stopped around 1965 when it became possible

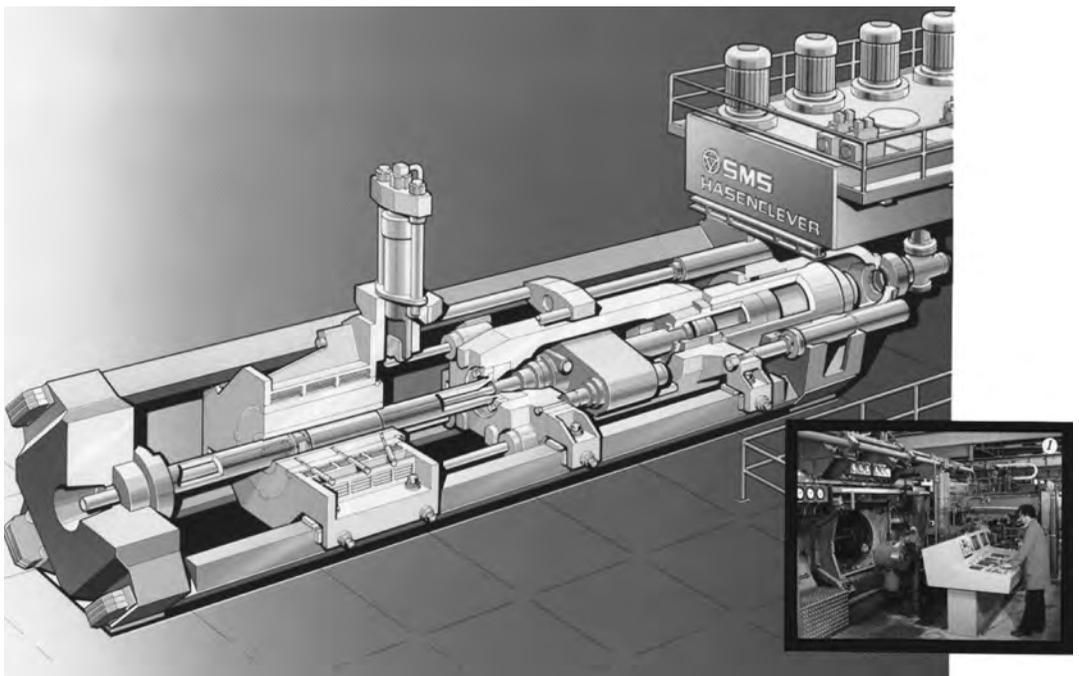


**Fig. 1.10** First rod and tube press (Arnold Schwiager, 1903)

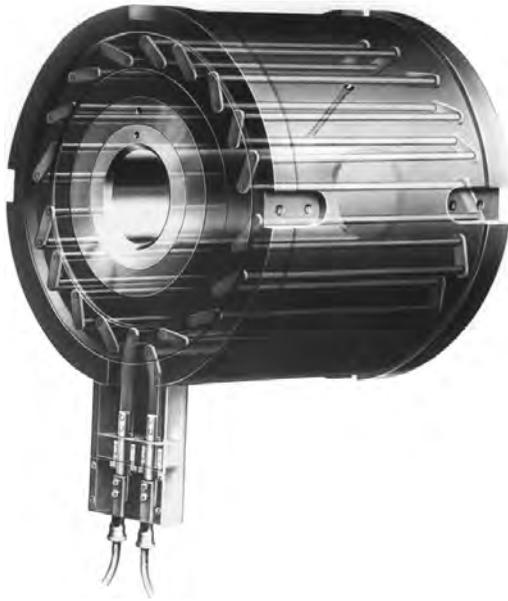
to improve the alignment of the press centerline, the guiding of the container, stem, and mandrel to such an extent that tubes with adequate concentricity were produced on horizontal presses. In spite of the high cycle speeds, the presses with a maximum capacity of 16 MN did not have sufficient power to process billets of sufficient size.

Around 1933, the vertical mechanical tube presses patented by Singer started to mass produce steel tubes. These vertical tube presses with a high number of strokes per minute for the mass production of steel tubes have been largely replaced by rolling processes that operate more economically with a higher productivity.

Containers, which had for a long time been produced as multipiece units but without any interference fit could operate only with specific press extrusion pressures of approximately  $300 \text{ N/mm}^2$ . It was only the introduction of two- or three-piece prestressed containers that enabled higher extrusion pressures to be used. Movable containers enabled the billet loading and the removal of the discard to be improved. The introduction of electric container heating (resistance and later induction heating) in 1933 replaced the previously used gas or coal heating and enabled aluminum to be processed (Fig. 1.12).



**Fig. 1.11** Extrusion press for tubes with an internal piercer



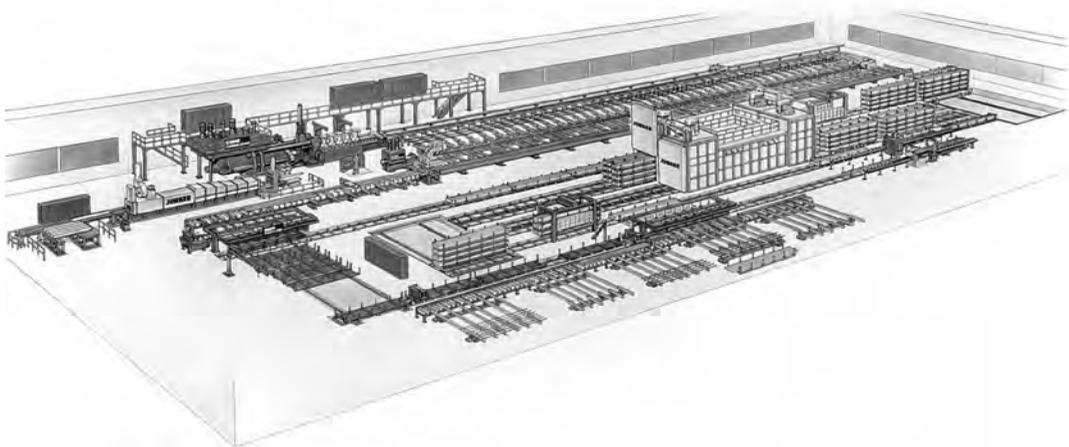
**Fig. 1.12** Three-piece container with induction heating

The rapid expansion of extrusion technology since 1925 gave rise to intensive investigation into the flow processes and deformation technology theories. These resulted in new developments in press construction and tooling technology.

For a long time it was standard practice to design each press from new to meet the needs of the application and the customer. Around 1960, multipurpose extrusion presses that could be used universally were developed in Europe.

Although Alcan has processed aluminum on horizontal presses since 1918, the breakthrough in aluminum extrusion came with the construction of airships and aircraft. Difficult-to-extrude high-strength aluminum alloys were developed in the 1930s (aluminum copper), and large product cross sections required powerful presses. The largest extrusion presses built up to 1945 had a press power of 125 MN. Around 1950, the preassembled short stroke press with variable direct oil drive (mounted above the press), and die slide or die rotate for rapid die changing, was developed in the United States. This enabled short dead cycles to be developed. These presses for aluminum alloys were built with press loads from 10 to 30 MN. They provided optimal production in combination with a high-speed gas-fired billet furnace in front of the press and a handling system with stretcher and saw for the profiles after the press. Aluminum profiles for windows and curtain walling could then be produced economically. The full layout of an aluminum extrusion plant is shown in Fig. 1.13.

Although experiments by R. Genders (1921, in England) into indirect extrusion resulted in the manufacture of these presses by 1925, the breakthrough of this process came with the indirect extrusion of brass wire (Hydraulik Co.). Improved designs and the application to difficult-to-extrude aluminum alloys ensured the increasing application of this indirect extrusion process. In contrast, the hydrostatic extrusion process has succeeded in only very specialized applications in spite of extensive research and numerous publications. One example is the extrusion of composite materials.



**Fig. 1.13** Complete aluminum extrusion plant (SMS Hasenclever)

## REFERENCES

- [**Bau 82**]: M. Bauser and E. Tuschy, Strangpressen—Heutiger Stand und Entwicklungstendenzen (Extrusion—Present Position and Development Trends), *Z. Metallkd.*, Vol 73, 1982, p 411–419
- [**Bis 73**]: A. Biswas and F.J. Zilges, Direktes, indirektes und hydrostatisches Strangpressen—Verfahrensbeschreibung und geschichtliche Entwicklung (Direct, Indirect and Hydrostatic Extrusion Process Description and Historic Development), *Aluminium*, Vol 49, 1973, p 296–299
- [**Dic 94**]: A. Dick, Deutsches Patent 83388, 1894
- [**Dic 97**]: A. Dick, Deutsches Patent 99405, 1897
- [**Nus 90**]: A.J. Nussbaum, Extrusion of Metals: The First Hundred Years, *Light Met. Age*, Vol 48, 1990, p 8–33
- [**Pea 61**]: C.E. Pearson and R.N. Parkins, *The Extrusion of Metals*, Chapman & Hall, 1960
- [**Pet 59**]: E. Petsch, Neues indirekt-Strangpreßverfahren für Metalldraht (New Indirect Extrusion Process for Metal Wire), *Z. Metallkd.*, Vol 50, 1959, p 629–637
- [**Wei 66**]: F. Weitzel, *Die Entwicklung der Strangpresse (The Development of the Extrusion Press)*, Edelstahlwerke Buderus AG, Wetzlar, 1966
- [**Wie 70**]: H. Wieland, *Die Geschichte des Strangpressens im Blicke der Wieland-werke (The History of Extrusion from the Viewpoint of Wielandwerke)*, Wielandwerke AG, Ulm, Germany, 1970