EXTRUSION PLANT FOR NON-FERROUS METALS.


INTRODUCTION.

The title of this paper may suggest that descriptive matter will be given on extrusion plant for the wide range of non-ferrous metals which are extrudable. Such is not the case, as to cover the complete range would entail a paper of some length, and therefore the subject has been condensed to encompass some of the plant used for the manufacture of extruded solid sections in "yellow" metals. However, references to other metals and alloys will be made from time to time as they may be of interest.

In view of the many applications calling for the use of extruded shapes, at this stage it may be helpful to those not already familiar with the methods employed to know what the main process is. Briefly, the extrusion process consists of forcing metal, heated to a semi-plastic state, by pressure through a steel die orifice, which is so shaped as to impart the required form to the stock. This process produces uniform cross-section bars of high tensile strength with surfaces smooth and sufficiently true to dimensions to require little, if any, machining. Extrusion as it is known to-day is a comparative new-comer among the methods followed in industry to fashion metal into useful forms; nevertheless, it has succeeded in attaining one of the foremost positions in these methods. Since the last war the rapid development in the use of extrusions has required great advances in the technique of metallurgy and engineering as applied to this particular process, and this war has stretched extrusion resources to the utmost, bringing in its train many new and complex problems in both fields. There are indications that further advances are taking shape, and it is probably quite safe to say that in the post-war era extrusion will play an even greater part in the field of semi-finished products. Already steel and other alloys of high melting point have been extruded, and there are signs that extrusion may have some scope in connection with "powder metallurgy." It is true to state to-day that there are few industries which do not or cannot use extruded sections in some way or another.

HISTORICAL SURVEY.

It is doubtful if an accurate date can be named for the origin of extrusion, but records exist to show that in 1797 a hydraulic engineer was granted a patent on a press for making pipes of lead and other soft metals of all dimensions. The idea of extrusion was probably the basis of design for the machine, though it is doubtful whether the machine ever operated satisfactorily.

In 1894 the late Alexander Dick obtained a patent on an extrusion press which laid the foundation of the current hot extrusion process for metals to receive good mechanical properties, such as the copper-base alloys which are commonly known as brass.

Hydraulic extrusion presses, though varying greatly in design and construction, are basically identical, and at the present time they continue to incorporate the principles expounded by Dick.

To Dr. R. Genders, the present Superintendent, Technical Applications Metals, Ministry of Supply, Great Britain, the industry is indebted for the great amount of research and experimental work he undertook in connection with the inverted method of extrusion which he introduced in England shortly after the last war.
PREPARING EXTRUSION BILLETS.

Extruded sections are produced from circular billets and for melting the metal charges crucible type or channel type induction furnaces are in common use.

In the main the capacity of the furnaces will be determined by the general run of extruded section it is desired to produce, but frequently the furnaces employed have a pouring capacity of the order of half a ton.

It is not proposed to discuss the crucible type furnace, as it has been in service for several years in many foundries, and its characteristics follow simple principles.

On the other hand, the design, construction and operating cycle of the channel type induction furnace offer a marked contrast to the crucible type furnace.

The principle of a channel type induction furnace is a copper coil which acts as the primary of a transformer, of which the secondary is formed by a narrow channel of molten metal. As the current passes through this secondary, it heats the metal, and at the same time sets up a vigorous circulation, due to electrical forces. These include:

1. Convection, due to the metal in the secondary channel being hotter than that in the main body of the furnace.
2. The phenomenon known as “pinch” effect, which tends to contract the cross-section of a conductor through which a current of high density is passed, and
3. Motor effect due to the tendency of the metal in each of the two sides of the slot to repel that in the other side.

The total effect of these forces is to cause a powerful circulation of the metal, thus increasing the speed of melting, and ensuring homogeneity.

The furnace lining can be monolithic or precast, the former type being the more popular one to date.

Whenever practical, the rammed monolithic furnace lining should be dried out gradually, and to this end the lining should be subject to natural drying for a period of fourteen days prior to the insertion and switching on of the electric heating elements to give artificial drying.

The melting cycle varies according to many factors, chiefly, the electrical rating of the furnace, the composition of the metal charge, and the condition of the loop. For instance, a 120 k.V.A. furnace required to pour 1105 pounds of 60/40 alloy will have a melt cycle of the order of fifty minutes under normal working conditions and a general average melting time lies between fifty to sixty minutes.

Brass melting furnaces of this type are made generally along established lines with pouring spouts, and with mechanical or hydraulic tilting equipment, both nose-tilting and centre-tilting types.

In a modern foundry it is usual to arrange for the furnaces to pour direct into barrel moulds mounted on turntables. These moulds vary in diameter and length, dependent on the container and size of extrusion press to be used. The bore tapers upwards to give a larger diameter at the bottom of the billet to facilitate extraction after casting. When the cast billets have been air cooled for about two hours they are ready to be “headed” and cut to the desired length. A fluifed saw, with inserted teeth, is frequently used for this operation, and during the cutting operation the billet is held in a hydraulic vise under a working pressure of around one ton p.s.i. One well-known make of fluifed saw will cut through a 6½ in. diameter brass billet in approximately fifteen seconds.
BILLET PREHEATING

Smooth working of the extrusion process requires the supply to the press of billets which are heated throughout to a uniformly semi-plastic condition, and frequently involves the control of their temperature within narrow limits.

A continuous type furnace is invariably employed for this purpose, and can be either of the sloping hearth type or the slotted hearth type. The second type has mechanical means of conveying the billets through the furnace, with the object of making their travel as positive as possible. Two massive chain conveyors, supported on air-cooled or water-cooled skid rails below hearth level, carry chairs of heat-resisting steel, 28 per cent. chrome, which extend through the hearth slots to support and carry the billets through the furnace.

For both types of furnace it is quite usual to overfire them when the heating medium is fuel oil, producer gas, natural gas, town gas or tar fuel. Electrical energy is also another source of heat, and Fig. 1 shows a typical electric furnace. It should be noted that the thermal efficiency of an electric furnace is high, being of the order of 75 per cent., whereas furnaces functioning on other heating mediums have much lower thermal efficiencies.

The holding capacity of the furnace will hinge on average press throughput, and desired soaking period, but as a guide it can be stated that two hours' soaking is quite often allowed for brass billets twenty-four inches long by six and a half inches in diameter. With this size of billet it is conceivable that the furnace load might approach five and a quarter tons.

Automatic zoned temperature control through two-point recording control pyrometers materially assists to bring the billets up to the extrusion state.

The hub of the extrusion mill is naturally the press, and it is proposed to describe a typical 1000-ton direct extrusion press, incorporating hydraulic and mechanical auxiliaries.

In regard to the power required to drive the press, this can be supplied either by direct pumping from vertical or horizontal hydraulic pumps, three-throw type geared directly to the motor, are chiefly used on account of their smooth delivery, dead weight or pneumatic type accumulators.

Opinions appear to differ widely on the relative merits of the systems of hydraulic power to the press. In the U.S.A. it would seem that the advocates of the closed hydraulic circuit, or direct pumping, are in the majority, yet in England and Germany leading press builders generally recommend the use of an accumulator. If the press ram speed is low, for duralumin the speed of extrusion is usually about six inches per minute, then power is invariably wasted if direct pumping is resorted to, and the accumulator is the better proposition.

There are several drawbacks to the dead weight type accumulator: heavy foundations are required to carry the load, and severe pressure surges are liable to occur in them, with risk of damage to pipe lines and control valve gear, due to the release of kinetic energy of the heavy moving mass when the withdrawal of pressure water is suddenly interrupted.

The pneumatic type accumulator has no moving parts, and as it comprises a number of forged steel bottles, there is a considerable saving in weight and space. One disadvantage of pneumatic accumulators is that when the water is at its lowest level in the bottle, which, when a
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A single extrusion press is being worked, will be towards the end of the extrusion stroke when a high pressure is often needed, the actual pressure available is slightly reduced, due to the expansion of the compressed air; they should therefore be given sufficient capacity to keep this variation within 10 per cent. Quite commonly, however, several presses are supplied from one large accumulator, which reduces pressure fluctuations.

In the cycle of press operations, idle movements occupy a considerable part, and as it is uneconomical to use pressure water for these a low pressure system is incorporated for this purpose, when the set-up includes accumulators. Direct pumping permits control of pressure through the medium of a choke valve; consequently, a wide range in pressure is readily obtainable for the different operations.

Reverting to the pumps, forced lubrication throughout the pumps and the speed reducer has gained favour, and among other features this system provides two outstanding safety factors. (1) The oil must reach a pre-determined pressure in both units before the electrical circuit to the prime mover can be completed; and (2) if the oil pressure in either unit falls below the set figure, under running conditions, the supply of electrical energy to the prime mover is interrupted through the opening of the main contactor. Diaphragm pressure switches are the main controls for such a hook-up.

Fluid velocities through the valves and valve boxes should be kept as low as possible, and a water velocity of the order of 15 f.p.s. should assist to keep the erosion factor to a minimum.

The normal working delivery manifold pressure will probably be of the order of two tons p.s.i., and this feature requires, (1) that the pumps shall be under suction head to take care of the acceleration head brought about by the speed of the pump rams, and (2) provision shall be made to look after the cyclic variation of discharge pressure. It is a simple matter to arrange for the suction manifold of the pumps to be supplied from a pressure vessel of sufficient capacity to look after the displacement of the hydraulic media occasioned each cycle of the press. In regard to the cyclic variation of discharge pressure, this can be met in two ways—(1) by an air chamber, and (2) by an alleviator.

PRESS EQUIPMENT.

Before giving a detailed description of the typical press mentioned previously, four slides will be shown to illustrate horizontal extrusion presses of various designs.

Fig. 2 shows a Krupp press of unorthodox design, with yoke frame and providing the alternative use of either the direct or the inverted method of extrusion. The bore of the container liner is parallel, and after extrusion a sweeper pad is inserted into the liner at the back end to eject the discard therefrom.

Fig. 3 shows an English press for 1500 tons for general purposes, and it will be noted that it is of the three-column type. In the foreground can be seen the die-head in the withdrawn position, also the vertical hydraulic locking bar mechanism.

Fig. 4 shows another English press of 2000 tons, and the following features are emphasised:—The die bridge sits on a stool, and six jack bolts and four lateral bolts are fitted to look after co-axial alignment and thermal expansion; the press punch has a nose for centreing the pressure pad; there is a chute for returning the pressure pads to the magazine.
Fig. 1. — Courtesy of "The Extrusion of Metals."

Fig. 2. — Courtesy of "The Extrusion of Metals."

Fig. 3. — Courtesy of "The Extrusion of Metals."

Fig. 4. — Courtesy of "The Extrusion of Metals."
Fig. 5. Courtesy of "The Extrusion of Metals."

Fig. 5 shows an American press of 2750 tons, and this is equipped with hydraulic shears to sever the stock from the discard.

The principal components of a typical 1000-ton direct extrusion press and its hydraulic and mechanical auxiliaries are:

1. The main cylinder and die bridges of cast steel.
2. Three tension columns which tie the two bridges together.
3. A combination bedplate fabricated from mild steel, electrically welded throughout, and subsequently stress relieved.
4. A cast steel main cylinder housed in the main cylinder bridge.
5. A chilled cast iron main ram, ground to give a mirror finish, with a depth of chill of over half an inch, and having a surface hardness of approximately Brinell 600.
6. A tail ram passing through a stuffing box at the rear of the main cylinder. The functions of this ram will be described later.
7. The tail ram carrier on two pivoted slippers, running on a common bedplate.
8. A cast steel main ram crosshead carried on slippers.
9. Container vicing and retraction rams and cylinders carried by the main ram crosshead.
10. A steel punch mounted at the front end of the main ram, and held in position by three collets and three aligning screws. The screws permit accurate centreing of the punch in relation to the container liner to keep the "shell" wall thickness under some measure of control. The punch also has a nose to centre the pressure pads.
11. A container holder, of cast steel, mounted on slippers running on the same baseplate as the main ram crosshead.
12. A forged steel container, loosely fitted in the container holder, having two sets of four radial inserts spaced at ninety degrees to take care of radial thermal expansion.
13. A hollow forged liner of nickel-chrome-molybdenum heat-resisting steel, tensile strength 80 tons p.s.i., equivalent to a hardness of approx. Brinell 363, shrunk, under pressure, into the container. The bore is taper 0.070 in. per foot length.
14. Pressure pads, which are placed singly behind the billet when in the liner to obviate flowing back over the punch during extrusion. On one face they are recessed to receive the nose on the punch.

15. A pressure pad elevator, built up in sections held together with small bolts which shear should the emergency arise, and thus prevent damage to the elevator as a whole.

16. A hydraulically operated billet loader with spring loaded claw.

17. An extrusion die cut oversize, to allow for the thermal contraction of the metal in cooling from the working temperature, and for cold drawing when an “as drawn” bar is specified.

18. A support pad, or bolster, for the extrusion die.

19. A die-holder and carriage, mechanically operated to give a reciprocating motion.

20. A hydraulic vertical locking bar.


22. Hydraulic butt shears.

23. A control rostrum.

The main ram packing is relieved of the weight of the main ram by the fitting of a tail ram. The tail ram also helps to guide the main ram, which results in better axial alignment.
Figs. 6, 7 and 8 show arrangements for supporting the main ram crosshead and a form of billet loader.

As the product flows through the extrusion die, it is lead on to a combined run-out and primary cooling bench. Sometimes insufficient attention is given to this bench, with the result that billets are cut wastefully, so that the extruded product can be handled by the limited length of the bench, and, secondly, internal stresses are set up if the extruded metal cools off on a bench of wrong design.

After the "leading-out" is complete, a pendulum type hot metal saw severs the extruded metal from the discard, which is taken over to the butt shears for cropping the butt off the shell.

When the product has cooled further it is conveyed to another hot metal saw, which cuts it into the desired lengths.

From this operation the product is placed on a secondary cooling bed until it has reached a low temperature.

Assuming an "as drawn" round product is required, then the following machines may be used:—A rotary pointer to reduce the diameter at one end of the bar to permit the entry of the bar into the aperture of the draw die. Frequently this machine is a converted screwing machine. Hot or cold swaging machines can also be used for pointing. A draw bench to give a sizing draw of approximately 0.015 inch. This machine comprises an endless chain, a horse and dogs for gripping the bar, and a draw die, which nowadays is often chromium-plated. Besides reducing the cross-section dimension of the bar, the cold draw increases the mechanical properties.

Reeling machines of the two or three roll type are in common use for straightening round bars. By reeling the bars, the surface tension set up during the cold drawing operation is relieved, although in some instances it is necessary to give a low temperature anneal.

The principle on which the bar reeling and straightening machine works may briefly be stated as follows:—The bar to be straightened is passed between two oppositely inclined rotating rolls, one concave and the other parallel or barrel shaped. A guide supports the bar horizontally at the intersecting axis of the rolls, and is adjustable vertically to suit the varying bar diameters. The parallel roller is supported in a slide, and its distance from the concave roll may be varied by a large handwheel, according to the bar diameter. The bar is gripped and rotated by the rolls, the inclination of which feeds the bar automatically through the machine. The path between the rolls is bow-shaped, the amount of bow being controlled by the angular position of the rolls, care being taken to maintain parallelism of the roll faces to ensure a good bearing on the bar over its full length. Since the length of the rolls is constant and the depth of the bow conveniently variable, a deflection suited to the diameter and elastic yield point of the material to be straightened is easily obtained.

Fig. 9 shows an English machine used for straightening hexagon bars.

An English firm is now making a Schumag type continuous drawing, cutting off and straightening machine, which has a high through-put, and Fig. 10 illustrates the English-built job.

On a cutting-off machine shown by Fig. 11, it is possible to partially sever the bar for the fracture test.

Finally, Fig. 12 shows a cold metal saw for cutting the products to finished length.
REFERENCES

Claude E. Pearson, “The Extrusion of Metals.”
“Industrial Furnaces, Various Types Described,” page 62 onwards.
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Swann, H. M.

**Title:**
Extrusion plant for non-ferrous metals (Paper)

**Date:**
1949

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**File Description:**
Extrusion plant for non-ferrous metals (Paper)