The Manufacture of Continuous Glass Fibres

PRESENT TRENDS IN THE USE OF PLATINUM ALLOYS

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One of the most exacting applications of platinum is in the production of glass fibre. This involves the rapid flow of molten glass at temperatures around 1300°C through a series of small orifices which must retain their size and alignment. Current trends in the design of platinum alloy bushings are towards a greater output of fibre per unit weight of platinum employed.

Almost all continuous glass fibres are manufactured by the attenuation of molten drops of glass exuding from nozzles located in the base of a special fibre drawing furnace called a bushing. Nearly all bushings are constructed from platinum alloy despite the high investment cost involved; one basic reason is that, when expressed in cost per kilogram of fibre produced, the use of platinum alloys is cheaper than the use of other metals, e.g., nimonic alloys. A second reason is that, at the operating temperatures required, metals other than platinum alloys do not have adequate mechanical strength. The main platinum alloys used are 10 and 20 per cent rhodium-platinum. The current trend of bushings design development aims at greater output of fibre per unit weight of platinum alloy employed.

Bushings are basically of two types:

(i) Remelt or marble bushings operating from cold glass marbles as the feedstock and fulfilling the dual functions of melting the glass and conditioning it to the correct temperature for fibre drawing (see Fig. 2).

(ii) Direct melt bushings, which are supplied with liquid glass near the operating temperature for fibre drawing and are attached to a feeder channel of a furnace into which the raw materials for glassmaking are fed (see Fig. 3).

Because of their dual function, remelt bushings are larger and weigh about twice that of direct melt bushings for the same output of fibre. For economic reasons, the majority of continuous glass fibres are now made from direct melt bushings and design development of remelt bushings, except for the production of special fibre products, has ceased. This article concentrates on direct melt bushings, although much of their development can be applied to remelt bushings also.

Bushing Design

Bushing design is always in a state of development. With an average operating life of one year it is rare that an old bushing is replaced by one of identical design; the nozzle sizes may have been increased to achieve an increase in output, or some structural weakness may have been eliminated. But of all the changes over recent years the most important is related to the size, spacing, and the manufacturing technique of nozzles. This has led to much closer spacing of nozzles and also to a reduction in the use of platinum alloy per unit weight of fibre produced.

Originally, nozzles were made by taking the base plate, pressing small indentations in it where the nozzles were due to be located, and then building up solid nozzles by melting platinum alloy wire and placing it drop by drop on the apex of each indentation. Periodically, during this build-up, each nozzle would be inserted in a small press-tool and the outside smoothed. When the nozzle build-up was completed the holes were drilled individually, including a counter-bore if required. It can be readily appreciated that the manufacture of base plates for bushings by this technique was extremely laborious. Technically it placed a limit on the minimum distance between nozzles since access was required not only for the welder but also for simple tools needed for shaping the outside of the nozzle as well as for centering tools required for ensuring that the holes drilled in the nozzles were central to the nozzle itself.

The consistency of nozzle shape and location was improved by pre-manufacturing solid nozzles and inserting them into holes in a base plate followed by welding around each joint. But this method also called for access around each nozzle on both sides of the base plate and did nothing to enable more nozzles to be placed in a base plate of given area.

The objective of placing more nozzles in a given area of bushing base plates was brought about by the coming together of two separate developments. These were the demonstration that a nozzle counterbore was not necessary in order to achieve efficient production rates, and a new method of nozzle manufacture.

Nozzle Manufacture

As referred to above, most nozzles were originally made with a counterbore (see Fig. 4 (*a*)): This stemmed from the early period when bushings were made from pure platinum; due to the low glass/platinum surface tension the nozzles were frequently wetted by glass which travelled up the outside of the nozzle and across to adjacent nozzles, thus covering the underside of the base plate with glass. This seriously interfered with fibre drawing operations. By providing a counterbore, that is by thinning down the

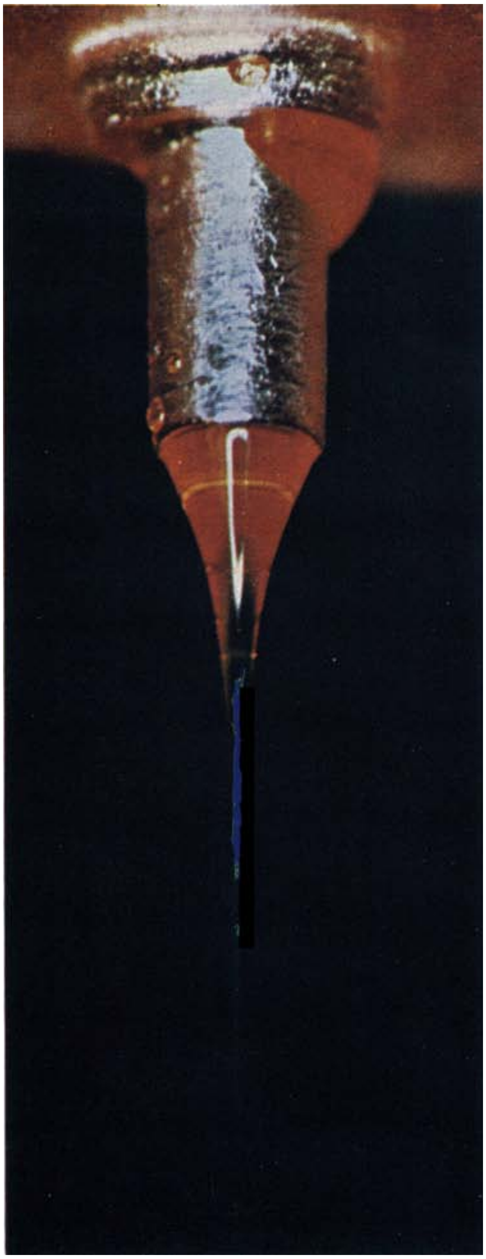


Fig. 1 Glass-fibre filaments are formed by drawing molten glass through hundreds of small orifices in a bushing constructed in a rhodium-platinum alloy. Great attention is given to the design of the bushing and to the method of manufacture of the nozzles to achieve maximum productivity. At the very high temperatures at which the process is operated only platinum alloys possess the necessary strength, while their use is most economical in terms of the amount of fibre produced.

Photograph by courtesy of Owens-Corning Fiberglas

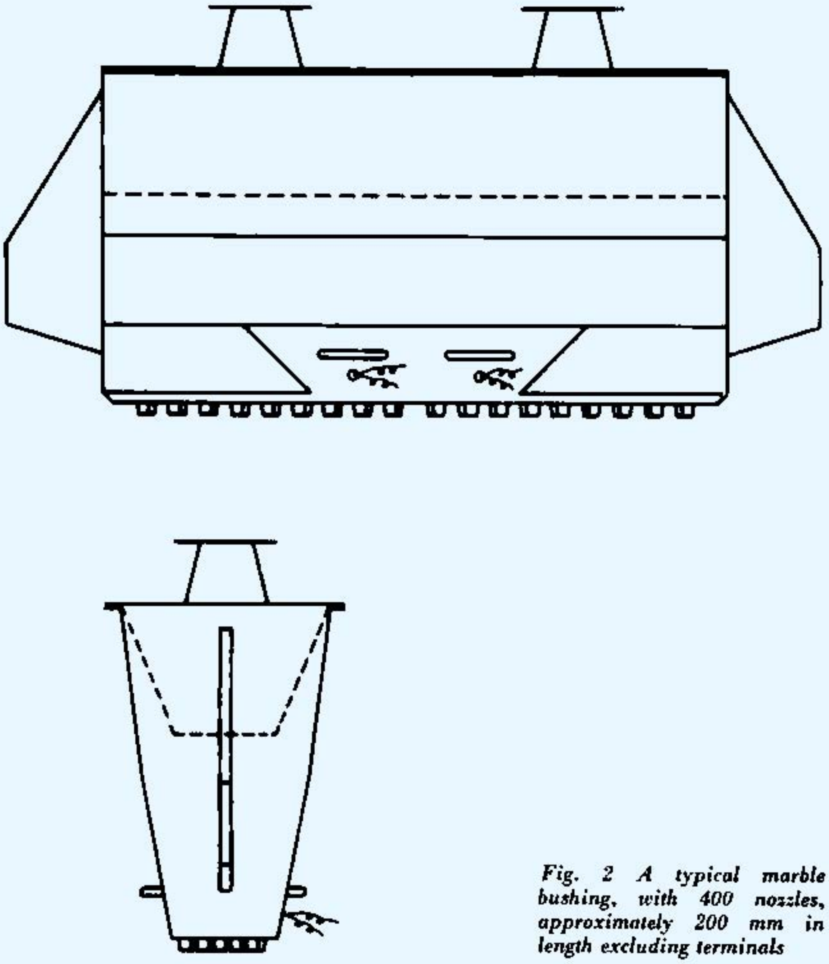


Fig. 2 A typical marble bushing, with 400 nozzles, approximately 200 mm in length excluding terminals

wall of a nozzle at the exit, this problem was reduced. Although the subsequent introduction of rhodium-platinum alloys increased the glass/metal surface tension, the nozzle counterbores remained until the underlying reason for meniscus stability at the base of the nozzle was more clearly understood. It is now sufficient to say that, for rhodium-platinum alloys, provided the wall thickness at the base of a nozzle is 0.2 mm, then the glass will not normally wet the outside of the nozzle. Nozzle counterbores are therefore no longer needed. The fact that nozzles could now be drilled in one operation and that a counterbore was no longer necessary meant that the overall wall thickness of nozzles could be reduced.

The next development was a new method of nozzle manufacture based on coining and deep-drawing (see Fig. 5). The starting material was a base plate of such a thickness that it contained slightly more than all the metal required for the base plate of final thickness plus the metal needed for the drilled-out nozzles. By a process of coining, the metal in excess of that required for the final thickness of the base plate is concentrated in those positions where nozzles will be located; these are then deep-drawn in stages, with annealing between the stages when necessary to prevent fracture. This gives nozzles which have very accurate outside and inside dimensions as well as a very smooth bore; however, they are still closed at the outlet end. The outlets are opened by punching followed by smoothing the ends of the nozzles by surface grinding. A typical bushing of this type is shown in Fig. 6 before mounting in refractory brick and its metal frame.

Rate of Flow of Glass

This development clearly involves considerable work on special tooling and an understanding of the behaviour of platinum alloys when subjected to deep-drawing. The process itself could clearly be made simpler if the nozzles could be reduced in length. Having demonstrated that, for the stability of the fibre drawing process, the counterbore was no longer necessary and that metal could be saved by thinning down the nozzle walls, then the next stage was to aim to make shorter nozzles, which would, however, maintain a given rate of glass flow.

The rate of flow of a liquid through a pipe is given by Poiseuille's equation:

$$F \propto \frac{r^4 h}{l\eta}$$

F is the rate of flow, r is the radius of nozzle bore in its narrowest cylindrical section, l is the length of the cylindrical section, h is the height of the liquid above the nozzle and η is the viscosity of the glass.

It is clear that if dimension l is reduced, then, in order to maintain the flow rate, dimension r must be reduced; if it is assumed that the clearance between adjacent nozzles is at a minimum for bushing manufacture then the distance between nozzles can also be reduced. Since several hundred nozzles are located in a bushing, even a small change in distance between adjacent nozzles can lead to a significant change in the number of nozzles that can be accommodated in a given base plate. For example, the base plate originally holding 400 of the longer nozzles, could readily be changed to accommodate about 600 of the shorter ones.

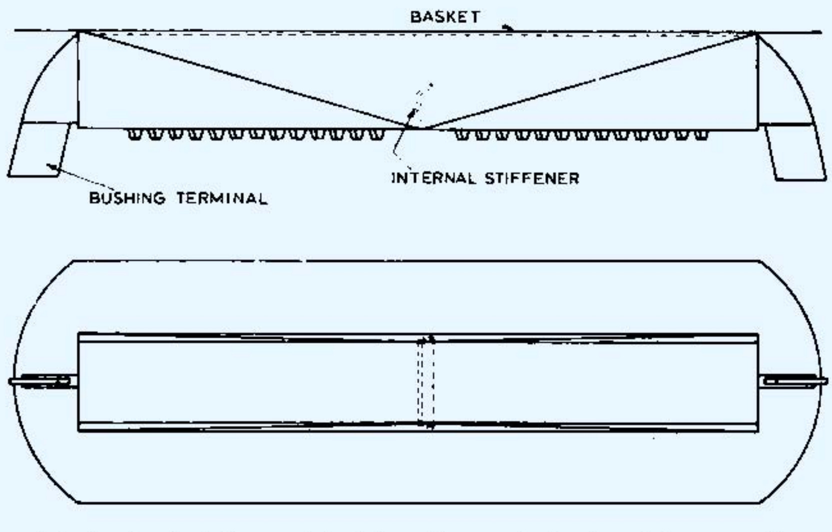


Fig. 3 A typical direct-melt bushing. Above, side elevation, below, view from underneath with nozzle plate removed. Overall length of nozzle plate about 300 mm for a bushing with 400 nozzles

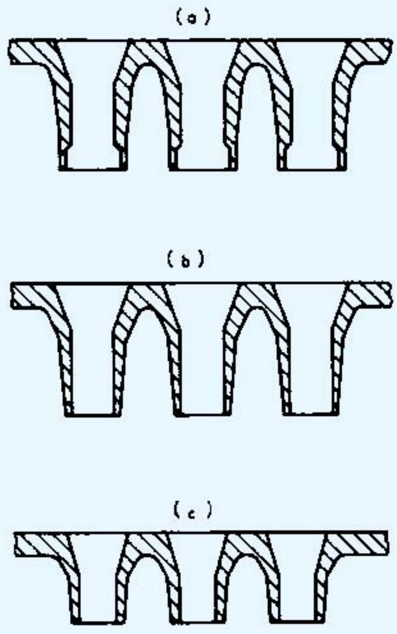


Fig. 4 Three examples of nozzle shapes giving the same production rates. It is clear that the nozzles in example (c) can be placed closer together, thus effecting a saving in platinum or allowing more nozzles per unit area of nozzle plate

With improvements in the operating efficiency of fibre drawing processes it became clearly desirable to increase still further the number of nozzles in the base plate of a given bushing since this leads to savings in the use of platinum alloy as well as to other production cost savings. However, even after placing nozzles as closely as possible together on the base plate, this inevitably leads to an increase in the size of the base plate and the bushing overall. Since platinum alloys, at the operating temperatures of bushings are liable to creep, larger bushings lead to increasing danger of distortion of the bushing during operation.

Distortion of the bushing is most serious on the base plate, since this can affect the efficiency of fibre drawing. The most serious danger is what is colloquially referred to as "uddering". This is entirely due to creep at the operating temperature under the small load imposed by the load of glass above the base plate. There are several techniques for minimising this defect. The first is to use an alloy of low creep; for this reason 20 per cent rhodium-platinum is now preferred to the 10 per cent rhodium-platinum alloy. (The costs per unit volume of the two alloys are practically identical.) Alternatively, the use of zirconia-stabilised platinum will reduce creep. A second or additional method is to place internal stiffeners on the bushing base plate to prevent the sagging commonly experienced (one may be seen in Fig. 3). In some cases, indeed, the base plate has been provided with an inverted V in the longitudinal direction to provide stiffening. However, this method has a drawback since the base plate requires more platinum. As in most cases, a compromise has to be struck between bushing life and operating efficiency. But, even so, bushings

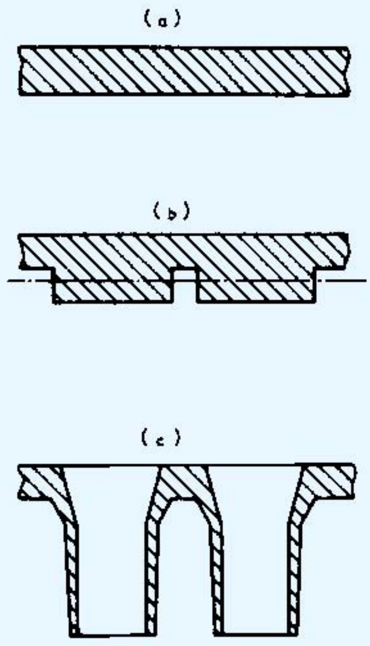
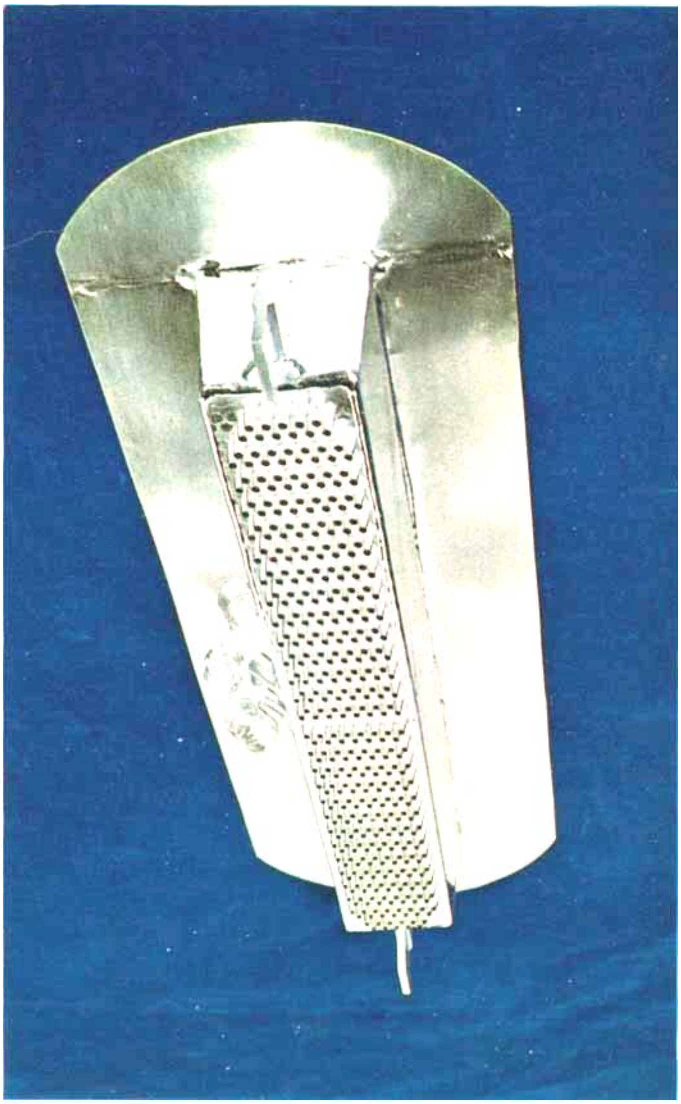


Fig. 5 Schematic diagram of the manufacture of a bushing base plate by coining and deep-drawing

Fig. 6 A completed 400 nozzle bushing, fabricated in 20 per cent rhodium-platinum alloy, before mounting in its support frame. The two pairs of coiled wires are the thermocouples



with over 1000 nozzles are now widely employed for many fibre products.

A further use of a platinum metal in association with fibre drawing is the use of nozzle shields. It was found some years ago that the stability of fibre drawing could be improved by placing radiation-absorbing shields between adjacent rows of nozzles. It was also found that the placing of these shields between alternate rows of nozzles was almost equally effective. Originally these fins were made of silver and attached to a water-cooled manifold acting as a heat sink. In some cases coolers made of flattened metal tubing were preferred, especially for use with bigger bushings, and have come into wide use. A suitable metal for these flattened tubes is rhodium-platinum alloy; a cheaper and equally effective metal is palladium.

Acknowledgement

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