CONFORM™ TECHNOLOGY
FOR COST EFFECTIVE
MANUFACTURE OF COPPER STRIP

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Introduction: BWE Ltd

BWE Ltd, formerly Babcock Wire Equipment Ltd, has operated from its Ashford headquarters in the Southeast of England since 1969, when the company first produced cold welding machines. Conform™ machines have been manufactured since 1976 when they were initially used for extruding round wire. Continuous development aimed at extending the capabilities of the Conform process led to an increasing number of applications including magnet wire, electrical conductors, refrigeration tube and ultimately, in 1984, the introduction of the Conklad™ process for aluminium clad steel wire and CATV and fibre optic cables.

The company has evolved into a highly specialised engineering organisation occupying 35,000 ft^2 of factory and office space close to Ashford town centre. Investment in Research and Development is centred on a complete Conform/Conklad plant used for developing new applications, carrying out pilot production for customers and for training customers' personnel. Investment in modern manufacturing methods has seen the replacement of traditional machines with computer controlled machines enabling the company to supply cost-effective high quality dies and tooling. The company's policy of strict quality control is backed up by the 6,000 ft^2 assembly and test bay where all plant is dry run prior to despatch.

In addition to designing and manufacturing Conform and Conklad Machines, BWE Ltd also designs and manufactures wire cleaning systems (Parorbital™) and a range of cold pressure welders for non-ferrous wire and rod.

BWE has a highly skilled work force dedicated to continuous improvement of design, manufacture, quality and performance. Sales and service are available through a world-wide network of agents and distributors who have direct access to the company's engineering and contract management departments ensuring that customers' requirements are dealt with promptly and efficiently.

The Conform/Conklad Process

The Conform process (Figure 1) uses a single wheel with a groove in its periphery to accept feedstock rod (or particulate feed in some cases). Since the area of contact in the groove greatly exceeds the area of contact between the feedstock and the enclosing shoe, rotation of the wheel drives the feedstock into the deformation zone where sufficient pressure and heat are generated for extrusion.

The twin groove process (Figure 2) was developed by BWE for extruding precision round and multi-void aluminium tubing and is used extensively to produce tubes for heat exchangers. The use of two feedstock rods gives several advantages. For hollow products, where the tooling contains a mandrel or male die, the two streams of

™ Conform, Conklad, Twinex and Parorbital are Trade Marks of BWE Ltd.

plasticised aluminium give a balanced flow of material through the tooling and hence a more concentric product. A wider range of product sizes is possible than with single groove operation and a higher output rate is possible.

A further advantage of the twin groove process is the ability to use the BWE Twinex™ system. The Twinex arrangement uses two feedstock rods entering a single wheel with two grooves. The two flows of metal enter special tooling with either a single or double die. For large sections, the two flows are mixed and extruded as a single product. For smaller sections the two flows do not mix, but emerge as two separate extrusions. The Twinex system emulates two machines in one, allowing the machine to cover a much greater range of product sizes and increasing output and reducing down time and wastage.

The BWE Conklad process (Figure 3) extends the capabilities of the Conform machine by utilising the twin groove tangential mode of operation. Here the tooling is positioned such that the product is extruded at a tangent to the wheel, and a core may be passed directly through the tooling. With CATV or fibre optic cores the aluminium sheath is extruded oversize in the tangential mode, allowing the core to be introduced through the specially designed tooling into the centre of the tube. After cooling the aluminium sheath is drawn to its final size, in-line with the Conklad process. The Conklad process for OPGW/CATV has been patented by BWE. For aluminium clad steel a similar arrangement is used but to achieve a metallurgical bond between the steel core and the aluminium sheath, the aluminium is extruded under pressure, directly onto the steel wire.

As well as product flexibility Conform/Conklad technology has other major benefits;

a) low capital cost
b) high production rates
c) close tolerances
d) low installation and maintenance costs
e) low energy consumption
f) continuous production
g) low scrap levels

The feedstock used for the production of copper strip is electrolytic tough pitch copper rod produced by continuous casting and rolling or oxygen-free copper rod, produced by the Rautomead RS casting machine. Rod diameters from 8mm to16mm can be used, depending on the product range and productivity required. For the Conform machine to operate under optimum conditions the feedstock rod should be fairly soft therefore a maximum yield stress of 130 MPa is specified.

Conform Machinery for the Manufacture of Copper Strip

A typical BWE Conform line for the production of copper strip consists of the following equipment (Figure 4):

- feedstock pay-off
- feedstock straightener
- (feedstock cleaning system)
- Conform machine
- Control system
- product cooling system
- (in-line Quality Control and measurement equipment)
- product handling system

These are described as follows:

Feedstock Pay-Offs and Straighteners

The feedstock pay-off and straightener are simple non-powered units, the Conform machine has sufficient power to pull off the feedstock rod through the straightener.

Feedstock Cleaning System

The feedstock, when it enters the Conform machine, must be free from oxide, oil, grease and any other contaminants. In some cases, in-line feedstock cleaning must be used, especially when the feedstock has been wax-coated to prevent oxidation. The feedstock cleaning system used with BWE Conform machines is either the BWE Parorbital system or an ultrasonic system.

The principle of the Parorbital system, shown in Figure 5, is a combined mechanical and chemical cleaning action. Each cleaning head comprises entry and exit air knives to prevent the escape of cleaning fluid, and six hydro-converters which perform the cleaning. Each hydro-converter contains two tungsten carbide dies, of slightly larger diameter than the feedstock rod. A high velocity jet of cleaning fluid is injected into the hydro-converter in such a way to create a powerful vortex around the feedstock rod. The vortex of fluid causes the copper rod to orbit at high speed, and scrubs the surface of the rod against the tungsten carbide dies.

Whether the cleaning system is Parorbital or ultrasonic, the combination of chemical and mechanical cleaning actions means that the cleaning fluids can be quite dilute. Therefore the hazards associated with highly corrosive chemicals are avoided.

Conform Machine

The heart of the Conform machine (Figure 6) is the grooved wheel and shaft assembly. This is mounted in roller bearings that incorporate multiple seals to retain oil and prevent the ingress of foreign material. A separate pressurised, filtered and cooled lubrication system ensures the bearings are adequately lubricated and correct operating temperatures are maintained. The bearings are held in a rugged steel frame that is extended to carry the pivoted shoe and the hydraulic shoe retaining system. Thus the relative deflections of the wheel and tooling are kept to an absolute minimum, enabling good product tolerances to be maintained, despite the high operating forces involved. The main shaft is driven by an infinitely variable, thyristor controlled DC electric motor, via an epicyclic gearbox. The power output envelope from the drive is matched to the production rates specified.

The pivoted shoe that carries the tooling is inserted and retracted by hydraulic cylinders operated from the pendant control panel on the machine. When closed the shoe is clamped in place by hydraulic cylinders. This system gives easy start up conditions and minimises the risk of damage from overload when operating an unfamiliar product, since the clamp pressure can be released, allowing the shoe to back off.

The BWE range of Conform machines consists of 5 models, the 285, 315, 350, 400 and 550 machines. The 350, 400 and 550 machines have Conklad, ie tangential extrusion capability. The numbers refer to the diameter of the Conform wheel. The power requirements of the machines increase with size; typically from 120 kW for a 285 machine to 400 kW for a 550 machine. The power requirements to convert copper rod feedstock into strip are quite low and therefore power requirements are not the main issue when selecting a Conform machine for this product. The limiting factors are the size of tooling that will fit into the machine and the output rate required. The capabilities of the machines for production of copper strip are listed in the appendix to this paper.

Control System

The Conform line is controlled by an industrial computer system with highly specialised software to provide the following features:

- Measurement and recording of operating parameters such as temperatures, speeds, machine load etc.
- Tabular display of primary, secondary and control parameters.
- Graphic display on one second time base of any four primary parameters over the last 24 hours.
- Graphic display on one tenth second time base of any four control parameters.
- File recording of primary, secondary and control parameters.
- Review of recorded files.
- Control of dynamic systems, such as pay-off, capstan, take-up, heaters, etc.
- Alarms.
- Calibration of system inputs and outputs.
- Set up and calibration of control loops.

Product Cooling System

The universal system for cooling the extrusion wheel and tooling and product produced consists of a storage tank with the product cooling trough mounted on top. To the rear of the tank is the pumping station containing a pump and heat exchanger for each cooling circuit. The high volume pump maintains the required level and flow velocity for the product cooling circuit. The low volume circuit supplies cooling to the extrusion wheel and tooling. Flow control valves for each of the cooling circuits are mounted on the front of the tank. A closed system is used to enable the water contacting the product and tooling circuits to be softened.

Special features of the cooling system have been developed to control the cooling rate of the product upon leaving the extrusion die. A rapid quench or a more gradual cooling rate are possible. This in turn gives control over the grain structure and hence properties of the extruded strip.

Quality Control and Measuring Equipment

Quality control and product measurement, if required, can be effected with in-line equipment. An eddy current detector will locate product defects. Product dimensions can be measured and recorded with a laser gauge. All of these devices operate at all line speeds and can be set up to give control and warning alarms for the purpose of Statistical Process Control.

Product Handling System

Product handling systems to produce coiled or straight length products can be provided. For coiled product, a drum take-up, controlled by a catenary system is used. The product can be wound onto a normal drum or a collapsible drum to produce coils. The catenary system is designed to handle a wide range of products and can be operated with various tensions down to near zero.

Tooling

The extrusion die is held in the pivoting shoe in a die chamber, (Figure 7). The die chamber holds the abutment(s) that fit into the wheel groove(s) and divert the flow of copper into the die chamber. The die chamber ensures accurate alignment of the tooling and allows tooling to be pre-assembled for rapid changes. The die chamber accommodates a wide range of product dies. The geometry and material selection of the tooling are essential to the production of a high quality product. Surface finish and dimensional tolerances depend on the accuracy of the tooling. The materials used for tooling must provide a balance of hardness, toughness and strength to give good wear rates along with the strength to resist the pressures and temperatures of extrusion.

Tooling is critical to the operation of a Conform plant, in terms of product quality and economics of production. In recognition of this BWE has invested in a state of the art tooling manufacturing facility. By using the latest generation of CNC machine tools, BWE can supply high quality production tooling at very economic prices. Technical support provided by BWE specialists ranges from monitoring tooling life and advising on design, materials and running conditions to carrying out development projects aimed at improving output or tooling life.

Manufacturing Operations

A Conform line for the production of copper strip can be carried out as a 24 hour operation at about 75% utilisation. Even from a cold start the machine quickly heats to operating temperature and can be at full output speed within a few minutes. Pre-heating the tooling to operating temperature in a furnace further improves this time.

Feedstock coils and full drums of product can be changed without stopping production. To change feedstock coils the line speed is reduced and the fresh coils of feedstock rod are placed on the pay-offs. The ends of the new coils are welded to the ends of the old coils using a BWE cold butt welder. The line speed is than ramped up to normal running speed and operation continued. Similarly the line speed can be reduced to remove a full drum of product and replace a new drum on the take up.

Manning requirements for a Conform line are low. Two operators are required to start the line and to change feedstock coils or output drums. During normal running only one operator is required to monitor the line and remove flash. In some plants one operator is used to run two lines.

Tooling changes are necessary to change products, or when a set of tooling reaches the end of its life. To change tooling quickly, the new tooling set is prepared in advance and can be heated to operating temperature in an oven. The extrusion is stopped, the shoe is opened and the old tooling set is removed. The new tooling set is inserted in the shoe, the shoe is closed and operation can begin immediately. In this way a tooling change can be carried out in only a few minutes. This ability to rapidly change products gives the benefit of very low stock holding requirements. The Conform machine can be very quickly set up to manufacture a particular size of strip. Many manufacturers supply copper strip to order, with no stockholding whatsoever.

Product Quality

Copper strip manufactured by the Conform process is used in electrical products such as magnets, transformers and motors, where dimensional and electrical properties are important. The electrical properties meet the requirements of all standards for such products and are generally better than rolled products. There is no porosity or local variation in dimensions. Surface finish is excellent. The strip is ready for enamelling or polymer insulation without any further treatment. The strip is produced in the fully annealed condition with a UTS of approximately 250 MPa, yield stress 70 MPa and elongation 50%. The grain structure is fine and regular, consistent with the regular flow pattern of material through the Conform machine. A major quality concern with rolled copper strip is the condition of the edge and corner radius. The rolling process usually produces inconsistent corners often with “roll-ins” i.e. small amounts of the surface rolled over. This problem does not exist with strip extruded by Conform where the corners radii and edges match the shape of the extrusion die.

Economics

Alternative methods to produce copper strip require the use of shaving, drawing, rolling and annealing equipment. The annealing stage is especially time-consuming, involving a heating, dwell and cooling cycle. By contrast the Conform process converts feedstock to annealed strip in one operation. Typically the production cost of copper strip manufacture by Conform is 30 to 50 % less than alternative methods.

Another major economic factor is inventory reduction. With a Conform operation, the raw material and work-in-progress levels are much lower than with a rolling mill. A rolling operation requires up to four sizes of input rod as well as inventory holding at each stage in the process. Also the lead time to produce a particular product means stocks of finished products are often held.

By contrast the Conform process produces a wide range of product sizes from a single infeed size. There is no inter-stage inventory since there is only a single process step. Since the lead time to produce a batch of strip can be as little as a few hours no stockholding of finished products is required.

Conclusion

Conform is well established as a reliable and cost effective method of manufacturing copper strip and similar products. Compared to alternative manufacturing methods, Conform has the following advantages:

- Lower capital outlay
- Lower labour cost
- Lower power cost
- Less space required
- Lower maintenance cost
- Lower replacement parts cost
- Less scrap
- Higher production rates
- Finished annealed product
- Greater lengths, limited only by take up capacity
- Short changeover times
- Lower stockholding requirements
- Shorter delivery lead times

Appendix

Conform Machine capabilities for Copper Strip Manufacture

Conform 285

General Parameters with 8.0 mm Diameter Feedstock

Minimum product dimension	0.80	mm
Maximum circumscribing circle diameter	28.00	mm
Minimum cross sectional area	4.00	mm^2
Maximum cross sectional area	65.00	mm^2
Maximum extrusion speed	100	m/min
Maximum output	340	kg/hr

General Parameters with 12.4 mm Diameter Feedstock

Minimum product dimension	1.50	mm
Maximum circumscribing circle diameter	28.00	mm
Minimum cross sectional area	15.00	mm^2
Maximum cross sectional area	150.00	mm^2
Maximum extrusion speed	100	m/min
Maximum output	800	kg/hr

Conform 350

General Parameters with 12.4 mm Diameter Feedstock

Minimum product dimension	1.50	mm
Maximum circumscribing circle diameter	35.00	mm
Minimum cross sectional area	16.00	mm^2
Maximum cross sectional area	150.00	mm^2
Maximum extrusion speed	100	m/min
Maximum output	850	kg/hr

General Parameters with 16.0 mm Feedstock

Minimum product dimension	2.00	mm
Maximum circumscribing circle diameter	60.00	mm
Minimum cross sectional area	25.00	mm^2
Maximum cross sectional area	300.00	mm^2
Maximum extrusion speed	100	m/min
Maximum output	1100	kg/hr

Conform 350 Twinex

General Parameters with (2x) 12.4 mm Diameter Feedstock

Minimum product dimension	1.50	mm
Maximum circumscribing circle diameter	15.00	mm
Minimum cross sectional area	(2x) 16.00	mm^2
Maximum cross sectional area	(2x) 60.00	mm^2
Maximum extrusion speed	100	m/min
Maximum output	1700	kg/hr

Conform 550

General Parameters with 19.0 mm Diameter Feedstock

Minimum product dimension	3.00	mm
Maximum circumscribing circle diameter	80.00	mm
Minimum cross sectional area	35.00	mm^2
Maximum cross sectional area	650.00	mm^2
Maximum extrusion speed	100	m/min
Maximum output	2200	kg/hr

Illustrations

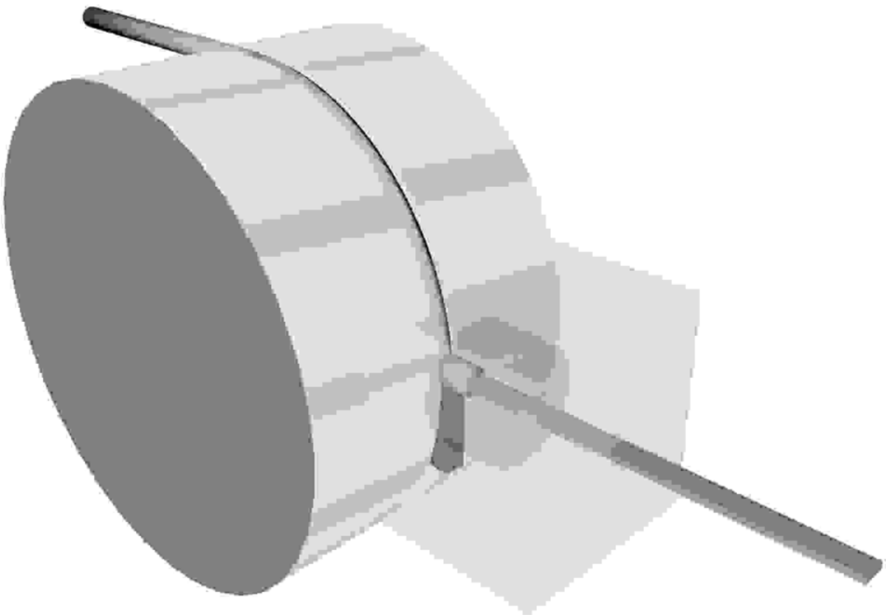

Figure 1 Conform Single Groove Radial Principle

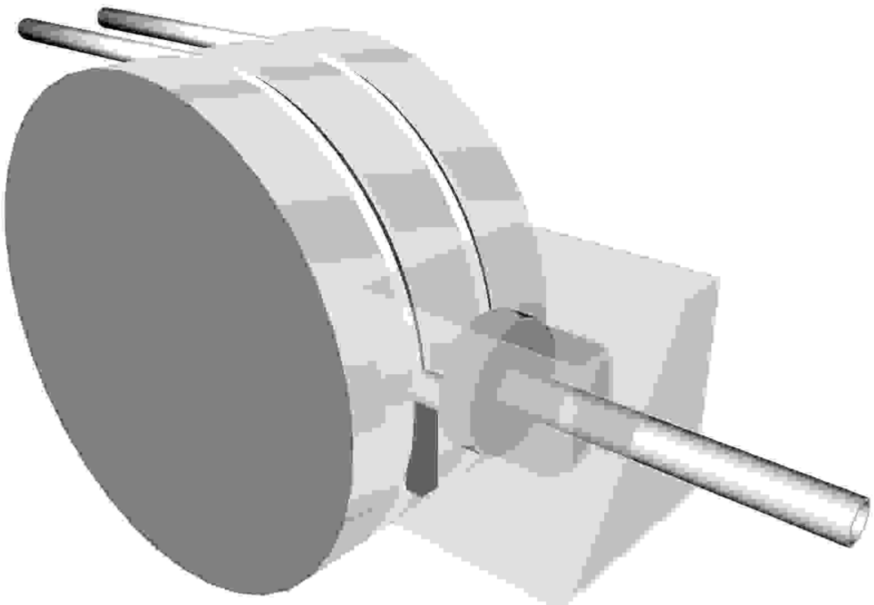

Figure 2 Conform Twin Groove Radial Principle

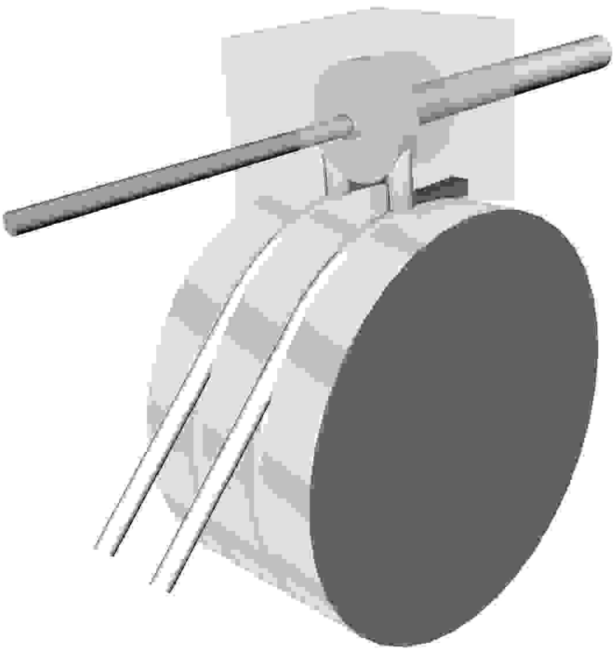

Figure 3 Conklad Twin Groove Tangential Principle

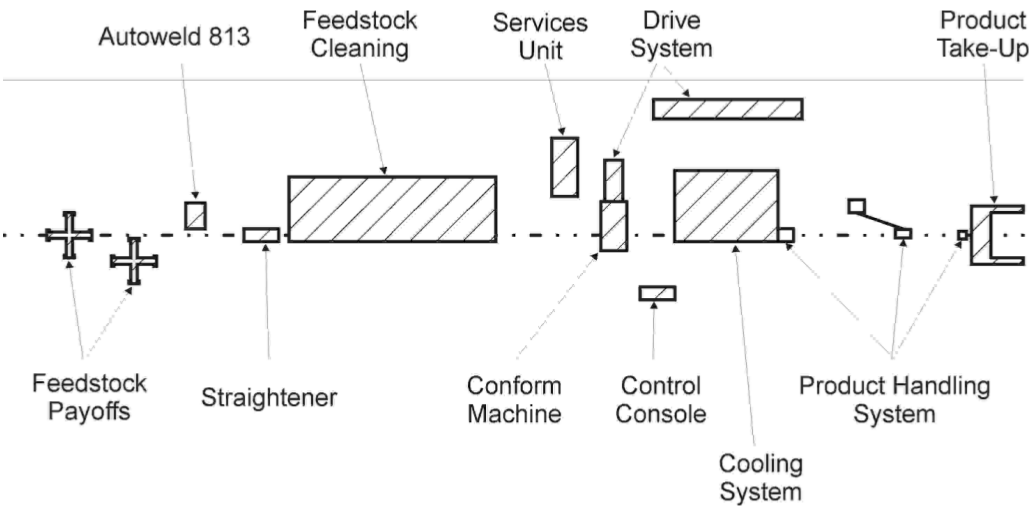

Figure 4 Conform Extrusion Line for Copper Strip

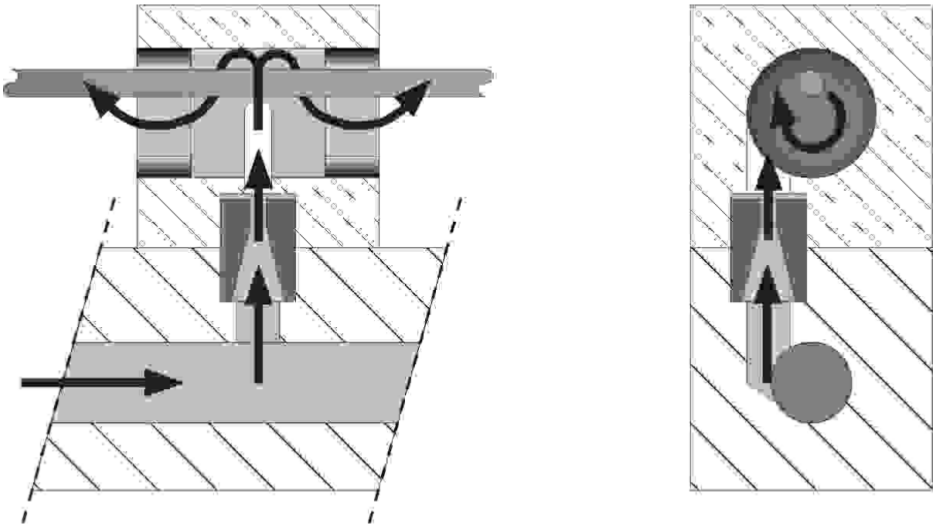

Figure 5 Parorbital Priciple

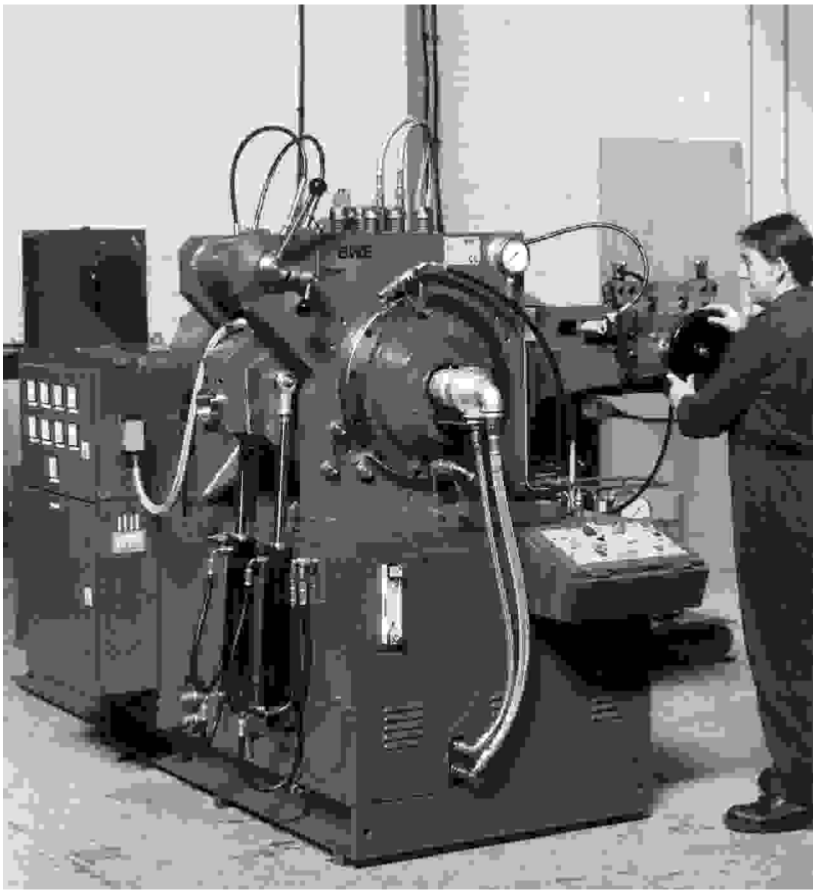

Figure 6 Conform 285 Machine

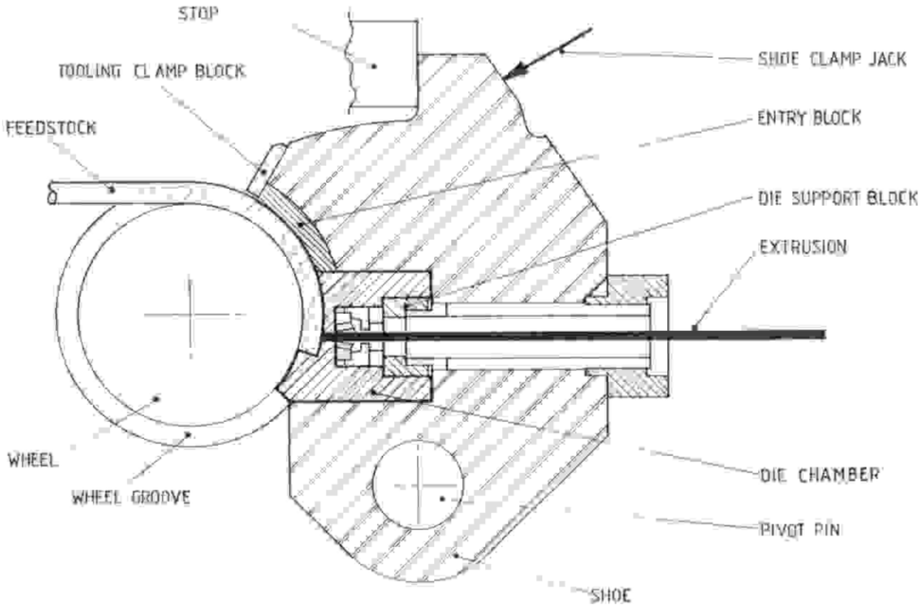

Figure 7 Conform Tooling Arrangement for Copper Strip