Precision Wire Forming

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ABSTRACT

An air-operated, semiautomatic wire former was designed and built at Mound Laboratory to form specific types of electrodes to be molded in plastic parts. Use of the semiautomatic wire former eliminates the sliding action of tooling on the surface of the electrode wire to be formed and properly aligns the crimped electrode surfaces to within required tolerance ranges. These are difficulties which are characteristic of conventional wire forming tooling. Interchangeable tooling is provided with the semiautomatic wire former for forming electrode wires in one plane; secondary tooling was designed and built for forming electrode wires in two planes; and a special series of tooling was designed for forming more complex wire forms.
The following difficulties are characteristic in forming one-piece design electrode wires: (1) the sliding action of conventional tooling scores the surface of the electrode wire and (in the case of clad wires) strips the cladding, and (2) the alignment of the crimped surfaces is not within the required tolerance range. Consequently, a semiautomatic wire former (see Figure 1) was designed and built at Mound Laboratory to eliminate the sliding action characteristic of conventional tooling and to position the crimped surfaces within the required dimension. The semiautomatic wire former was designed using two folding leaves or hammers that rotate around a center point coincident with the center point of the radius formed in the wire loop. This eliminates the sliding action, and the form ground on the hammers and forming anvil maintains the same relative position, thus ensuring the position of the crimped section of wire within the required tolerance. Interchangeable tooling was provided for forming electrode wires in one plane. Secondary tooling was designed and built for forming electrode wires in two planes. Also, a special series of tooling was designed for forming more complex electrode wire forms.

In conjunction with wire forming fixtures, a Metal Fourslide Forming Machine (The A. H. Nilson Machine Co., Shelton, Conn.) was purchased and tooled for forming large quantities of wires (see Figure 2). Wire straightening and cutoff equipment was purchased to support activities associated with the wire forming program. These activities include stretch straightening, roll straightening, and counter rotating straightening.

**DESIGN OF SEMIAUTOMATIC WIRE FORMER**

The primary design considerations that were used for the semiautomatic wire former are as follows:

1. The semiautomatic wire former had to be designed to prevent the sliding action of tooling which could score soft wire material and strip clad wires.

2. The location of the crimped or flattened surfaces of the electrode wire had to be in the same relative location when the wire was looped to form a one-piece wire.
FIGURE 1 - Semiautomatic wire former showing air cylinders.
FIGURE 2 - Metal Fourslide Forming Machine.
3. In many instances the formed electrode wire required a secondary forming operation which necessitated special tooling. In some instances special tooling was designed in series for forming complex electrode wires.

4. Tooling for automatic and semiautomatic wire formers required interchangeable designs for forming various wire shapes and diameters.

5. Dimensional control of the electrode wires and adjustment of the semiautomatic wire former and tooling were essential due to the required accuracy for positioning the electrode wires for molding in plastic.

**TYPES OF WIRE FORMS**

The wire forms vary from a simple loop design to complex open-end forms. Figures 3 through 7 show some of the wire forms and stages of completion as the part is progressed through tooling. Types of electrode wire forms are listed below.

1. The wire form shown in Figure 3 is a 0.0179-in. (0.4547-mm) diam copper wire with offsets and flats. This type of wire can be formed on the semiautomatic wire former.

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**FIGURE 3 - Copper electrode wire with offsets and retaining flats.**
2. The wire form shown in Figure 4 is a one-piece design wire with offsets but without retaining flats; an offset of 0.0418 in. (1.0617 mm) is required in the vertical plane. The first operation was formed in the semiautomatic wire former, and a secondary operation was required for the vertical offset.

![Figure 4 - One-piece design electrode wire with offsets but without retaining flats.](image)

3. A one-piece design wire (not shown) with a 90° bend 0.413 in. (10.490 mm) from the center of loop required a secondary operation to form the 90° bend.

4. The two-piece wire form shown in Figure 5 required special tooling to form the bend and flat. The tooling was designed to form two parts per stroke.

![Figure 5 - Two-piece wire form with bend and flat.](image)
5. The wire form shown in Figure 6 required special tooling to form the one-piece wire. Three forming fixtures were designed for this type of wire form.

FIGURE 6 - Sequence of operations required to form one-piece design electrode wire.
6. The wire form shown in Figure 7 requires a left- and right-hand form and can be formed on the Metal Fourslide Forming Machine.
FIGURE 7 - Electrode wire formed on the Metal Fourslide Forming Machine (The A. H. Wilson Machine Co., Shelton, Conn.) showing left- and right-hand form.
Initially, the semiautomatic wire former shown in Figure 1 was designed with interchangeable tooling to form electrode wires of the type shown in Figure 3. Typical tooling used in the semiautomatic wire former is shown in Figure 8. The semiautomatic wire former is air operated using two 2-in. (5.1-cm) air cylinders. Cylinder No. 1 operates the nesting slide, and cylinder No. 2 operates the forming hammers through two adjustable cam followers. During operation the operator places a precut wire of suitable length between the forming anvil and hammers. The slide is moved into position by cylinder No. 1 clamping the wire for forming (see Figure 9). Cylinder No. 2 is then actuated forming the shape of the electrode wire (see Figure 10). The operations are then reversed and the wire removed. To interchanged tooling the anvil holding fixture is removed allowing the anvils and hammers to be removed and replaced by tooling for a different type of wire form. Approximately 30 min are required to replace the tooling and to adjust the wire former for a different type of wire form. Approximately 15 sec are required for cycle time to load and to form the wire.

FIGURE 8 - Typical tooling used in semiautomatic wire former.
FIGURE 9 - One-piece electrode wire in position for forming in the semi-automatic wire former.

FIGURE 10 - One-piece electrode wire after forming in the semiautomatic wire former.
The tooling used to form and to flatten the wire form shown in Figure 5 was designed to operate in an air press. The wires are first cut to length and chamfered in an automatic screw machine. Spring-loaded pressure pads are used to grip this type of wire for required forming and to maintain straightness during flattening. Two wires are placed in the wire former by the operator, and the press is actuated to form the wires. The parts are removed by the operator after forming. The air press is operated by two interlocked palm valves for safety. The load and cycle time for this type of wire is approximately 30 sec for two parts.

A series of three fixtures was required to complete the form in Figure 6. The wires are cut to length and chamfered in an automatic screw machine. A wire of the required length is placed in the first fixture (see Figure 11). The two end loops are formed at a given distance and angle. The wire preformed in the first fixture is placed in the second fixture. In this fixture (see Figure 12) the loops are formed to the required angle or offset to form contact spacing upon completion of the form. The fixture is designed for use in an air press and is mounted in a die set for alignment. In operation the part is placed on the two folding leaves over locating pins. The forming leaves are designed so that pressure from the press ram causes them to hinge up to the required angle, thus giving support to the entire wire loop during forming. Upon completion of cycle the die is opened allowing the leaves to return to a flat position. The formed wire is then placed in the third fixture (see Figure 13).

![Figure 11](image-url)

**Figure 11** - Tooling used in semiautomatic wire former to shape first form of electrode wire.
FIGURE 12 - Tooling used in semiautomatic wire former to shape second form of electrode wire.

FIGURE 13 - Tooling used in semiautomatic wire former to shape third form of electrode wire.
to form the center loop to required spacing. This fixture is designed for use with an air press and is mounted in a die set for accurate alignment of forming members. The part is nested in a spring-loaded nest to hold the part securely during forming. When the tool is closed, the upper punch contacts the part to be formed to initiate bending (this action clears the nest). The spring nest travels approximately 1/16 in. (1.59 mm) and completes the form by setting the radius of the wire loop as it bottoms out on the die set. The press is then reversed, and the part is removed.

Another type of wire form is a one-piece design with a 90° bend 0.413 in. (10.490 mm) from the center of the loop. The first operation in forming this type of wire is made on the semiautomatic wire forming fixture. The loop, offsets, and flats are also formed in the semiautomatic fixture. However, a hand fixture was designed and built at Mound Laboratory to complete the 90° bend.

**METAL FOURSIDE FORMING MACHINE**

The Metal Fourslide Forming Machine is a high production machine obtained in order to automate wire forming requirements. An additional feature of the Metal Fourslide Forming Machine is reliability and the upgrading of straightening, feeding, and cutoff of wires to be formed.

The wire form shown in Figure 7 requires a left- and right-hand wire of similar form, and the quantity required made it a suitable product for the Metal Fourslide Forming Machine. Tooling for these two wire forms, provided by the A. H. Nilson Machine Co. (Shelton, Conn.) when the machine was purchased, was redesigned and modified to provide a more suitable part and to provide for the interchange of tooling when required. It is possible to form this wire type shown in Figure 7 at a rate of 80 parts/min.

The machine was adapted to magazine feeding so that it is capable of feeding precut parts from the magazine into the forming tools. In the present tooling setup, the magazines hold up to 4000 precut wires which provide an approximate 45-min operation time. The magazines are loaded in a specially designed loading fixture using a vibratory chute to feed and orient the wires (see Figure 14). The magazine loading operation requires approximately 10 min. Two magazines are provided for each wire length which allows for loading of one magazine while the other is on the machine; in this way the machine is supplied with a continuous flow of parts. The Metal Fourslide Forming Machine is also provided with a roll straightener and a counter rotating straightener, either of which may be used depending upon the type of wire to be fed into the machine.

There are two major disadvantages to the Metal Fourslide Forming Machine. (1) The tooling setup does not have the interchangeable features that would be required for short-run production. (2) The sliding motion of the forming tools tends to mark soft wire material or strip cladding. These disadvantages are due to tool design and can be improved by a design modification.
WIRE STRAIGHTENING AND CUTOFF

Stretch Straightening  The stretch straightening and cutoff machine shown in Figure 15 was obtained to provide a method of straightening soft wires ranging from 0.016 to 0.032 in. (0.406 to 0.813 mm) in diameter and from 0.5 to 18 in. (12.7 to 457.2 mm) long. The machine is capable of providing a supply of wires for the forming fixtures that have been developed. Production rate of this machine varies with wire length requirements. It is possible to straighten and cut to length 200 wires/min in the shorter lengths [0.5 to 2 in. (12.7 to 50.8 mm)]; the time increases as the wire increases in length. The machine operates on a continuous feed system. The wire is fed from a spool under tension that provides stretch for the straightening operation and into a solenoid-operated cutoff tool. The speed and time of cutoff are variable to control wire length. The tolerance on electrode wire lengths that are cut by this machine is +1/16 in. (±1.59 mm).

Roll Straightening  The roll straightener furnished with the Metal Four-slide Forming Machine was adapted to the wire stretch straightening machine to further utilize the feed and cutoff capability of the straightening machine. The roll straightening technique was favorable for hard alloy wires with production rates comparable to those of soft wires.

Counter Rotating Straightener  The counter rotating straightener was obtained for use with the Metal Four-slide Forming Machine and was also adapted to the wire stretch straightening machine so that it is possible to use the feed and cutoff portions of the straightening machine. The
FIGURE 15 - Stretch straightening and cutoff machine (The A. H. Nilson Machine Co., Shelton, Conn.).
counter rotating straightener is supplied with nylon shoes in the straightening member to eliminate marking soft alloy and clad wires; the straightener can also be used to straighten hard alloy wires with good results.

CONCLUSION

Although the semiautomatic wire former and related tooling are still being developed and tested, preliminary results indicate that the semiautomatic wire former satisfactorily fulfills the wire forming requirements of Mound Laboratory and is an improvement over conventional techniques.