

METHOD AND APPARATUS FOR CREATING SPACED OPENINGS IN HOLLOW DEVICES

FIELD OF THE INVENTION

- 5 The present invention relates to a method and apparatus for creating spaced openings in hollow devices. In particular, the present invention pertains to a method and apparatus for creating openings in waveguides economically and reliably.

BACKGROUND OF THE INVENTION

- Waveguides are used for facilitating the transmission of wireless signals therethrough for the purpose sending and receiving data and more recently for measuring and detecting critical parameters such as the position and velocity of transportation vehicles. An example of such application is disclosed in U.S.
15 Patent No. 5,684,489.

- Although the theoretical aspects of waveguides are well understood, equipment suppliers encounter great difficulty in meeting the stringent tolerance for waveguides and other similar hollow devices. In other words, the distance of
20 the openings in the waveguides has to be maintained in order for the signal sensing units and the processing modules to read and processing the signals correctly. Prior art methods and apparatus for creating spaced openings in waveguides are unable to do so consistently and economically because of the inherent limitations of the processes and/or the necessity of rework.

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There are generally three methods for fabricating hollow devices such as waveguides: (1) metal punching, (2) laser cutting, and (3) milling. Conventional

metal punching using fixed die is not suitable for creating multiple well-defined spaced openings in elongated hollow devices because the die cannot be located conveniently within the devices. Similarly, conventional turret punch arrangement is also not suitable.

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Laser cutting tends to leave sputter formations on the underside of the openings. Such formations are difficult to remove and cause the openings to be imperfect. Furthermore, debris such as splatters are left in the interior space of the hollow devices. If they were not removed effectively, they would
10 impede the transmission of wireless signals therethrough. However, it is cost ineffective to remove splatters from hollow devices.

Milled parts have burrs on the upper and lower sides of the cut edges. These burrs on the under side are difficult to remove and cause the openings to
15 become unsuitable for transmitting wireless signals. Inevitably chips are deposited within the elongated hollow devices due to the application of cutting fluids and coolants and difficult to remove.

Most commercial laser cutting machines and milling machines have limited travel
20 working tables and require re-staging of hollow device in order to produce multiple well-defined and precisely spaced openings on it. These re-staging cause inaccuracy and require tight control and inspection to ensure that the machined parts are able to meet the dimensional specifications.

OBJECT OF THE INVENTION

It is an object of the present invention to provide a method of creating multiple well-defined openings on long hollow devices.

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It is yet another object of the present invention to provide a method of creating multiple well-defined and precisely spaced openings on long hollow devices.

It is a further object of the present invention to provide a method and apparatus
10 for creating multiple well-defined and precisely spaced openings on long hollow devices economically and efficiently.

It is yet a further object of the present invention to provide a method and apparatus for creating multiple well-defined and precisely spaced openings on
15 long hollow devices economically, modularly and efficiently.

SUMMARY OF THE INVENTION

An apparatus for forming multiple well-defined and precisely spaced openings
20 on long hollow devices features at least one extendable die unit, at least one die holder, at least one piercing assembly, and at least one indexing unit cum alignment fixture. When the long hollow device is aligned by the die alignment fixture and properly indexed, the apparatus extends the extendable die unit into the long hollow device before the piercing assembly creates multiple well-
25 defined and precisely spaced openings without excessive chips or the need to rework the device. As such, a method for creating well-defined and precisely

spaced openings on long hollow devices is realised economically and efficiently.

BRIEF DESCRIPTION OF THE DRAWINGS

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Fig. 1 is a right, top, perspective, elevational view of an apparatus according to a preferred embodiment of the present invention.

Fig. 2 is a right, top, perspective, elevational view of the extendable die unit of
10 the present invention.

Fig. 3A is a top, plan, elevational view of the extendable die unit according to Fig. 2.

15 Fig. 3B is front, partial cross sectional view of the extendable die unit according to Section A-A in Fig. 3A.

Fig. 4A is a left, top, perspective, elevational view of the movable piercing unit of the present invention highlighting the punch unit.

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Fig. 4B is a right, bottom, perspective, elevational view of the movable piercing unit of the present invention highlighting the locating features.

Fig. 5 is a right, top, perspective, elevational view of the piercing actuator unit of
25 the present invention without the extendable die unit.

Fig. 6 is a right, top, perspective, elevational view of the piercing actuator unit of the present invention with the extendable die unit.

Fig. 7 is a right, top, perspective, elevational view of the die holder unit of the present invention.

Fig. 8 is a right, top, perspective, elevational view of the work piece indexing unit of the present invention.

Fig. 9 is a right, top, perspective, elevational view of the die alignment fixture of the present invention.

Fig. 10 is a right, bottom, perspective, elevational view of the die alignment fixture of the present invention.

Fig. 11 is a top, plan, elevational view of the apparatus of the present invention highlighting the die holder unit, the piercing actuator unit, and work piece indexing unit in relations to the extendable die unit.

Fig. 12 is a front, partial cross sectional, elevational view illustrating the initial set-up with the extendable die unit being extended into a long hollow device and before the actuation of the piercing unit.

Fig. 13 is a front, partial cross sectional, elevational view of the extendable die unit being extended into a long hollow device and after the first piercing operation.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 is a right, top, perspective, elevational view of an apparatus according to a preferred embodiment of the present invention. The invention is a modular apparatus for forming multiple well-defined and precisely spaced openings on long hollow devices such as waveguides. The apparatus comprises at least one die holder unit 20, at least one piercing actuator unit 60, at least one work piece indexing unit 80 and at least one die alignment fixture 100. The piercing actuator unit 60 further comprises at least one extendable die block 1 and at least one movable piercing unit 40. In the preferred embodiment of the present invention, the apparatus is aligned in a linear orientation to facilitate the forming of multiple well-defined and precisely spaced openings on long hollow devices. It should be understood by one skilled in the art that the invention can be modified to align in orientations other than linear.

Fig. 2 is a right, top, perspective, elevational view of the extendable die unit 1 of the present invention. The extendable die unit 1 comprises at least one die base 2, at least one cam tie 5, at least one cam actuator 8 and at least one die block 10. The cam tie 5 rests on top of the die base 2, and is in turn coupled to the cam actuator 8 on one hand and the cam links 4a and 4b on the other. The cam actuator 8 is coupled to at least one rod end bearing 9 which in turn is coupled to the die holder 20 (shown in Figs. 1 and 2); the cam tie 5 is coupled with at least two lateral cam links 4a and 4b which in turn are coupled to movable cam 6a and 6b respectively. The die block 10 is a solid piece with a plurality of linear roller bearings 11, inserts 13, cam guide 15, and locating holes 17 disposed on the top working surface. Each of the inserts 13 features at least one cavity 18 or 19 that has the shape of the well defined opening of the long hollow device 199. As will be described in Fig. 12, the locating holes 17

facilitate the alignment of the extendable die unit 1 by means of the die alignment fixture 100 and the long hollow device 199 just prior to the piercing operation.

Fig. 3A is a top, plan, elevational view of the extendable die unit 1 according to Fig. 2. In this specific example, four inserts 13 are disposed on the top working surface of the die block 10. Fig. 3B is front, partial cross sectional view of the extendable die unit 1 according to Section A-A in Fig. 3A. A plurality of guide posts 3 are disposed on the die base 2 for locating the die block 10 through linear bearings thereon. The die block 10 is shown coupled with a plurality of retainers 16 on top of the die base 2 with the movable cams 6a and 6b and fixed cams 14 therebetween. The die block 10 is restricted to limited movement in directions of 200 and 300 resulting from the dwell and rise of movable cams 6a and 6b. On the underside of the die block 10 is a backing plate 12 for providing support to the inserts 13 of the die block 10 and a plurality of fixed cam 14. In particular, the cavities 18 or 19 of the inserts 13 feature tapered widen opening below the top working surface of the die block 10. The broader base of the cavities 18 and 19 terminate with the openings on the backing plate 12. The cavities of the inserts 13 facilitate the creation of well defined openings on the long hollow device without leaving burrs on the underside of the device.

Again in Fig. 3B, the cam tie 5 is shown disposed on top of the die base 2 and between the cam actuator 8 and the die block 10. The cam tie 5 features an opening for receiving the frontal portion of the cam actuator 8 which is coupled to a mounting bracket 7 which is in turn coupled to the die base 2. The mounting bracket 7 has a rod ending bearing 9 for coupling to the die holder unit (not shown in this figure but in Figs. 1 and 11).

- Fig. 4A is a left, top, perspective, elevational view of the movable piercing unit 40 of the present invention highlighting the punch unit. The movable piercing unit 40 cooperates with the extendable die unit 1 to create well defined and spaced openings on long hollow devices. The movable piercing unit 40 comprises at least one body 41 upon which at least one linear guide rail 43 and at least one linear slide 44 are disposed. Coupled to the linear slide 44 is at least one punch unit comprising of at least one punch holder 45 and at least one punch 46. In the preferred embodiment of the present invention, the punch features two punches 46a and 46b for creating multiple openings. The punches are coupled fixedly to the punch holder 45 with clamp plates 47. At least one compression spring 48 is disposed between the body and the punch holder 45 for providing force for the movement of punch holder 45 in direction 200. A plurality of openings 52 are disposed on the body 41 for permitting the punches 46a and 46b to extend through the bottom surface of the unit. At least one retainer 49 is provided to control over the linear movement of the punch. At least one handle 50 is also provided to transport the movable punch unit 40.
- Fig. 4B is a right, bottom, perspective, elevational view of the movable piercing unit 40 of the present invention highlighting the locating features. The underside of the movable piercing unit 40 reveals at least one locating block 42 having at least two pairs of locating pins 51a and 51b for cooperating with the cavities 18 and 19 on the die block 10 of the extendable die unit 1. The locating pins 51a and 51b is spaced at a predetermined distance from the punch openings 52 of the body 40. This arrangement provides the proper

distance between the well defined openings on the long hollow device each and every time the present invention creates such openings.

Fig. 5 is a right, top, perspective, elevational view of the piercing actuator unit 5 60 of the present invention without the extendable die unit 1. The piercing actuator unit 60 comprises a structure 66 having at least one work surface 65 for receiving at least one extendable die unit 1 (not shown in this figure but in Fig. 6), at least one bracket 61 extended from the working surface 65, and at least one actuator 62 for activating the punches 46a and 46b of the movable piercing 10 unit 40 (not shown in this figure but in Figs. 4A and 4B). In the preferred embodiment of the present invention, the structure is a standalone work bench. At least two manual operated control inputs 63 and at least one emergency stop input 64 are disposed on frontal and substantially at hip level for permitting human operator to control the piercing actuator unit 60, the extendable die unit 1 15 and work piece indexing unit 80. Needless to say, the inputs 63 and 64 are electrically connected to control box 33 (not shown in this figure but in Fig. 7) which houses control element/devices capable of providing pre-determined operation sequences.

20 Fig. 6 is a right, top, perspective, elevational view of the piercing actuator unit 60 of the present invention with the extendable die unit 1. The extendable die unit 1 is aligned adjacent to the bracket 61 and substantially below the actuator 62 such that the movable piercing unit 40 (not shown in this figure) can create well defined openings on long hollow device 199 (not shown in this figure but in 25 Figs. 12 and 13) that is introduced slidably within the extendable die unit 1. The extendable die unit 1 is coupled to the die holder unit 20. The structure and

function of the die holder unit 20 shall be elaborated next in connection with the description of Fig. 7 below.

Fig. 7 is a right, top, perspective, elevational view of the die holder unit 20 of the present invention. The die holder unit 20 comprises at least one structure 32 having at least one work surface 34, a plurality of conveyors 30 and 31, at least one end bracket 29, and at least one tube 21 for connecting it to the extendable die unit 1 (not shown in this figure) on one end and the end bracket 29 on the other end. The conveyors 30 and 31, the end bracket 29 and the tube 21 rise on top of the working surface 34. The conveyors 30 and 31 are positioned on each side and substantially in parallel with the tube 21. In the preferred embodiment of the present invention, the tube 21 terminates on the end closer to the extendable die unit 1 with at least one bearing mounting block 22 and at least one fork end 25. The fork end 25 has at least one pin 27 for receiving the rod end bearing 9 of the extendable die unit 1 (not shown in this figure). The bearing mounting block 22 of the tube 21 has at least one roller shaft 23 which in turn has a plurality of roller bearing 24 for supporting the tube 21. Opposite the bearing mounting block 22 the tube 21 terminates in at least one rod end bearing 26. The end bracket 29 is coupled to the rod end bearing 26 with at least one fixed fork end 28 and at least one pin 27. Optionally, a control box 33 for providing actuation of the extendable die unit 1, the work piece indexing unit 80 and the piercing actuator unit 60 are located beneath the working surface 34 of the die holder unit 20. It should be understood by one skilled in the art that this control box can easily be located elsewhere, for example underneath the piercing actuator unit 60 or the work piece indexing unit 80.

Fig. 8 is a right, top, perspective, elevational view of the work piece indexing unit 80 of the present invention. The work piece indexing unit 80 comprises at least one structure 85 having at least one work surface 86, at least one conveyor segment 84, at least one actuator 81, at least one mounting plate 82 and at least one clamping actuator 83. The conveyor segment 84 supports a long hollow device 199 such as a waveguide (not shown in this figure but in Figs. 12 and 13). The clamping actuators 83 when actuated apply clamping force to the long hollow device 199. The clamping actuator 83 cooperates with the actuator 81 to index the long hollow device 199 in direction 400 through the alternate clamping and unclamping of the clamping actuator 83. The clamping actuator 83 and the actuator 81 are set to operate when the long hollow device is within the gripping zone of the clamping actuator 83.

Fig. 9 is a right, top, perspective, elevational view of the die alignment fixture 100 of the present invention. The die alignment fixture 100 comprises a plate having datum surfaces 103a, 103b and 104 respectively; the plate also has a plurality of slots 102 corresponding with locating pins 51a and 51b of the movable piercing unit 40. Furthermore, a plurality of locating pins 101 are disposed adjacent to the slots 102 for facilitating the locating of die alignment fixture 100 into locating holes 17 of the extendable die unit 1.

Fig. 10 is a right, bottom, perspective, elevational view of the die alignment fixture 100 of the present invention. Here, a better view of the locating pins 101 is shown.

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Fig. 11 is a top, plan, elevational view of the apparatus of the present invention highlighting the die holder unit 20, the piercing actuator unit 60, and work piece

indexing unit 80 in relations to the extendable die unit 1. The layout of the present invention is modular. The die holder unit 20, the piercing actuator unit 60 and the work piece indexing unit 80 are individually scalable for facilitating the mass production of well defined and spaced openings in long hollow devices economically.

Fig. 12 is a front, partial cross sectional, elevational view illustrating the initial set-up with the extendable die unit 1 within the long hollow device 199; the die alignment fixture 100 and movable piercing unit 40 located onto the extendable die unit 1 and before the actuation of the movable piercing unit 40. The long hollow device 199 is initially supported by conveyors 30 and 31 of the die holder unit 20. The die block 10 of the die extendable unit 1 is extended in direction 200 by actuation of the cam actuator 8 in the direction of 400. The alignment of the location pins 51a and 51b of the movable piercing unit 40 with cavities 18 and 19 of the die block 10, of the die alignment fixture 100 with the die block 10, of the datum surface 103a and 103b of the die alignment fixture 100 with long hollow device 199, of the locating pins 101 of the die alignment fixture 100 with the die block 10 through locating holes 17 (not shown in figure but in Fig. 2), ensures that the precise location of the intended openings are determined just prior to the piercing operation. The actuator 62 lowers the punches 46a and 46b towards the work piece 199 directly over the inserts 13 of the die block 10 to provide the intended openings at locations 800 and 801 on the long hollow device 199.

After piercing of openings at locations 800 and 801, the actuator 62 raises and allows the punches 46a and 46b to leave the long hollow device 199 through the force provided by the compression spring 48 of the movable piercing unit

40. The die block 10 of the extendable die unit 1 is retracted in direction of 300 by actuation of the cam actuator 8 in direction of 400. The movable piercing unit 40 is moved away for the removal of the die alignment fixture 100. After removal of the die alignment fixture 100, the long hollow device 199 is indexed through a predetermined distance by manual means in the direction of 400. Once again, the die block 10 of the extendable die unit 1 is extended in direction of 200 by actuating the cam actuation 8 in the direction of 500. Next, the movable piercing unit 40 is located onto the long hollow device 199 by inserting the locating pins 51a and 51b of the movable piercing unit 40 into the openings of the long hollow device 199 and cavities of the die block 10 at locations 18 and 19 for creating openings on the long hollow device 199 at locations 802 and 803 (not shown in this figure but in Fig. 13).

Fig. 13 is a front, partial cross sectional, elevation view of the extendable die unit 1 being extended into the work piece 199 and after the first piercing operation has been performed. The piercing of the punches 46a and 46b of the movable piercing unit 40 on the long hollow device 199 creates the well defined and spaced openings at locations 802 and 803 respectively. The scrap materials 299 from the piercing operation drop onto the bottom interior surface of the long hollow device 199 without leaving any burrs on the new openings or oily deposits on the interior thereof. At the end, the processed long hollow device 199 is withdrawn and scrap materials 299 could be removed by simple means.

The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The presently disclosed embodiments are, therefore, to be considered in all respects as

illustrative and not restrictive, the scope of the invention being indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are, therefore, to be embraced therein. For example, the long hollow device or work piece 199 is assumed to be rectangular in cross
5 section area. It should be understood by one skilled in the art that the present invention is equally effective in creating well defined and spaced openings in long hollow devices with different cross sectional area profiles.

CLAIMS**I Claim:**

- 5 1. An apparatus for receiving hollow devices and creating openings thereon effectively, said apparatus comprising:
- at least one die holder unit biasing said hollow devices in preparation for creating openings thereon;
- 10 at least one die alignment fixture disposed in spaced relationship with said die holder for aligning said hollow devices;
- at least one piercing actuator unit coupled to said die holder unit and said die alignment fixture for providing at least one extendable die unit and at least one movable piercing unit in spaced relationship for accepting said hollow devices slidably therethrough and creating opening on said hollow devices; and
- 15 at least one work piece indexing unit coupled to said piercing actuator unit for conveying said hollow devices therethrough and aligning said hollow devices in preparation for piercing operation at said piercing actuator unit,
- 20 whereby well defined and spaced openings are created on said hollow devices economically and efficiently.
- 25 2. The apparatus for receiving and creating openings on hollow devices as in claim 1 wherein said die holder unit comprises at least one end bracket, at least one tube, at least one roller bearing and at least one conveyor.



3. The apparatus for receiving and creating openings on hollow devices as in claim 1 wherein said piercing actuator unit comprises at least one extendable die unit, at least one movable piercing unit, and at least one actuator.

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4. The apparatus for receiving and creating openings on hollow devices as in claim 3 wherein said extendable die unit comprises at least one die base, at least one cam tie, at least one cam, at least one cam link, at least one guide post, at least one cam actuator and at least one die block.

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5. The apparatus for receiving and creating openings on hollow devices as in claim 4 wherein said die block further comprises at least one locating hole, at least one backing plate, at least one linear bearing and a plurality of inserts and cavities thereon.

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6. The apparatus for receiving and creating openings on hollow devices as in claim 4 wherein said cam tie is coupled to said cam link and said cam, said cam tie being further coupled to said cam actuator and said die base.

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7. The apparatus for receiving and creating openings on hollow devices as in claim 1 wherein said work piece indexing unit comprises at least one conveyor segment, at least one actuator and at least one clamping actuator.

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8. The apparatus for receiving and creating openings on hollow devices as in claim 7 wherein said clamping actuator operates cooperatively with at least one actuator and at least one conveyor segment with said hollow device.
- 5 9. The apparatus for receiving and creating openings on hollow devices as in claim 1 wherein said die alignment fixture comprises at least one locating pin, at least one slot and at least one datum surface.
- 10 10. The apparatus for receiving and creating openings on hollow devices as in claim 1 wherein said movable piercing unit comprises at least one body, at least one locating pin, at least one linear guide rail, at least one linear slide, at least one punch, at least one compression spring and at least one handle.

