INTEGRATED, AUTOMATED, VARIABLE SHEET METAL FORMING AND ASSEMBLY SYSTEM

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Abstract
An integrated, automated, variable sheet metal forming and assembly system includes a plurality of robotic material conveyors and a forming subsystem including at least one sheet metal draw press apparatus. An assembly subsystem is in series with and downstream from the forming subsystem. The assembly subsystem includes a roller hemming apparatus. An inspection subsystem is in series with and downstream from the assembly subsystem. The plurality of robotic material conveyors are operable to convey assembly workpieces to and from the subsystems.
FIG - 5
INTEGRATED, AUTOMATED, VARIABLE SHEET METAL FORMING AND ASSEMBLY SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims the priority of U.S. Provisional Application No. 60/846,219 filed Sep. 21, 2006.

TECHNICAL FIELD

[0002] This invention relates to sheet metal fabrication systems, and more particularly to manufacturing processes for automotive vehicle closure assemblies.

BACKGROUND OF THE INVENTION

[0003] It is known in the art relating to sheet metal fabrication systems to execute forming processes at separate locations from assembly processes. It is also known to transport the formed parts from a forming location to an assembly location as well as to store formed part inventory at an off-site location prior to transportation to an assembly location. It is further known to use separate forming equipment to form the panels for each type of assembly.

SUMMARY OF THE INVENTION

[0004] The present invention provides an integrated, automated highly flexible (“hi-flex”) system that integrates forming, assembly, and inspection into a single manufacturing process. Sheet metal blanks enter the assembly system and certified finished assemblies are outputted from the system. The assembly system may be used to manufacture automotive closure assemblies, doors, deck lids, hoods, hiflases, or other similar panels.

[0005] More particularly, an integrated, automated, variable sheet metal forming and assembly system includes a plurality of robotic material conveyors. The system also includes a forming subsystem including at least one sheet metal draw press apparatus. An assembly subsystem is in series with and downstream from the forming subsystem. The assembly subsystem includes a roller hemming apparatus. An inspection subsystem is in series with and downstream from the assembly subsystem. The plurality of robotic material conveyors are operable to convey assembly workpieces to and from the subsystems.

[0006] In one embodiment, the forming subsystem may include at least one electromagnetic pulse apparatus in series with and downstream from the sheet metal draw press apparatus. For example, the forming subsystem may include two electromagnetic pulse apparatuses in parallel with each other. Alternatively, the forming subsystem may include a laser trim apparatus in series with and downstream from the sheet metal draw press apparatus. The forming subsystem may also include a roller hemming apparatus in series with and downstream from the sheet metal draw press apparatus.

[0007] Further, the forming subsystem may include at least one die changer for changing dies of the draw press apparatus. For example, the forming subsystem may include two die changers and a plurality of die sets having a plurality of individual die. The individual die of each die set also may be divided amongst the two die changers. The forming subsystem further may include at least one scrap conveyor adjacent the draw press apparatus for conveying scrap metal pieces away from the forming subsystem. The roller hemming apparatus of the assembly subsystem may include a plurality of interchangeable anvils.

[0008] The inspection subsystem may include a white light inspection apparatus.

[0009] A method for integrated sheet metal forming and assembly includes the steps of: providing a plurality of robotic material conveyors for conveying sheet metal workpieces; introducing a sheet metal blank to a forming subsystem including a sheet metal draw press apparatus to form a sheet metal panel; conveying the sheet metal panel to an assembly subsystem including a roller hemming apparatus; assembling a plurality of sheet metal panels in the assembly subsystem by using the roller hemming apparatus to form a hemmed sheet metal assembly; and conveying the sheet metal assembly to an inspection system for robotic inspection of the sheet metal assembly.

[0010] Prior to conveying the sheet metal panel to the assembly subsystem, the sheet metal panel may be conveyed to an electromagnetic pulse apparatus. The electromagnetic pulse apparatus may be used to perform at least one of a trim operation, a re-strike operation, a flange operation, and a pierce operation on the sheet metal panel.

[0011] Alternatively, prior to conveying the sheet metal panel to the assembly subsystem, the sheet metal panel may be conveyed to a laser trim apparatus. The laser trim apparatus may be used to perform robotic laser trimming of the sheet metal panel. Further, prior to conveying the sheet metal panel to the assembly subsystem, the sheet metal panel may be conveyed to a roller hemming apparatus. The roller hemming apparatus may be used to perform a hemming operation on the sheet metal panel such as flanging or similar.

[0012] The method also may include the steps of: providing a plurality of die changers in the forming subsystem for changing dies of the draw press apparatus; providing a plurality of die sets including a plurality of individual die; and dividing the individual die of each die set amongst the plurality of die changers.

[0013] These and other features and advantages of the invention will be more fully understood from the following detailed description of the invention taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] In the drawings:

[0015] FIG. 1 is a schematic view of a first embodiment of an automated manufacturing process in accordance with the invention having an integrated forming, assembly, and inspection system;

[0016] FIG. 2 is a schematic view of a second embodiment of an automated manufacturing process in accordance with the invention having an integrated forming, assembly, and inspection system;

[0017] FIG. 3 is a schematic view of a third embodiment of an automated manufacturing process in accordance with the invention having an integrated forming, assembly, and inspection system; and

[0018] FIG. 4 is a schematic view of a fourth embodiment of an automated manufacturing process in accordance with the invention having an integrated forming, assembly, and inspection system;
[0019] FIG. 5 is a schematic view of a fifth embodiment of an automated manufacturing process in accordance with the invention having an integrated forming, assembly, and inspection system; and

[0020] FIG. 6 is a schematic view of a sixth embodiment of an automated manufacturing process in accordance with the invention having an integrated forming, assembly, and inspection system.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Referring now to the drawings in detail, numeral 10 generally indicates an integrated, automated, variable sheet metal forming and assembly system that integrates forming, assembly, and inspection processes into a single manufacturing cell. The integrated forming, assembly, and inspection system 10 may be used for producing sheet metal panel assemblies such as automotive vehicle doors, deck lids, hoods, liftgates, or other similar panel assemblies.

[0022] A manufacturing system and process 10 in accordance with the invention includes a blank panel washer and feeder that cleans sheet metal blanks and feeds them into the system. A material handling robot moves the sheet metal blanks from the feeder to a stamping draw press. Rotary die changers allow for the changing of the dies used in the stamping draw press to allow for the forming of inner and outer panels by the draw press as well as for the forming of various sizes and shapes of panels. The setting of the die is completely automated within a production run and therefore there is no manual setting of the dies during a production run. Between stamping operations, one or more material handling robots move in-process workpieces from the draw press to one or more automated adjustable in-process racks. The automated adjustable in-process racks can be positioned for various sizes and shapes of panels, even if the shape changes in process from one die operation to following die operations. There is no external storage of inner and outer panels throughout the process. One or more scrap conveyors may remove stamping operation offal from the draw press cell. After the draw operation is completed, a cushion may be optionally employed.

[0023] The stamping draw press may be used for all the stamping operations including but not limited to re-strike, trim, pierce, and flanging. The stamping draw press may be equipped with multiple die change equipment capable of drawing, trimming, and flanging. The stamping equipment is also common for the production of both the inner panel parts and the outer panel parts. Therefore, a single stamping draw press may be used for production of both inner and outer panels. Only the dies used in the draw press are part specific. The stamping draw press may be hydraulically operated or may be electrically and mechanically operated. Further, the stamping/forming portion of the system may be operated to run individual die hits in small batch sizes, rather than for one part being run through all stamping operations before the next part is begun. For example, lot sizes of 10 may be run through the stamping portion of the system.

[0024] Another material handling robot may transport the formed panels from the draw press to a laser trim cell or an electromagnetic pulse cell. The laser trim cell or electromagnetic pulse cell is optionally used depending on the capabilities of the die stamping process. The laser trim cell or electromagnetic pulse cell can reduce die trim or pierce functions of the die stamping cell and also may eliminate a die from the stamping process.

[0025] The laser trim cell includes one or more flexible nesting stands having a breaking feature. The material handling robot is used as the servo positioning unit to move the nesting features of the nesting stands into position for the various sizes and shapes of panel workpieces being run through the system. The nesting stands hold the panel workpieces in position for the laser trim operation. The laser trim cell also includes a laser trim robot that performs the laser trim operations. The laser trim robot also handles scrap from the laser trim operation or optionally from trim or piercing operations of the stamping dies of the draw press cell depending upon the die process used. A turntable oscillates the panel nest stands and out of the laser trim robot work envelope. A scrap conveyor removes laser trim offal from the laser trim cell. The scrap conveyor exiting the laser trim cell may cooperate with one of the scrap conveyors removing waste from the draw press cell. The laser trim cell may also include an enclosure around the periphery of the cell.

[0026] The electromagnetic pulse cell includes one or more anvils that nest the panels allow for the performance of trim, re-strike, flange, or pierce operations on the panels. The cell may include an anvil changing track that allows for interchange of anvils within the cell. The track may be powered or driven by robot. The electromagnetic pulse cell also includes an electromagnetic pulse robot that mounts an electromagnetic pulse apparatus such as an electromagnetic pulse head that performs the electromagnetic pulse operations. A scrap conveyor may remove waste pieces from the electromagnetic pulse cell. The scrap conveyor exiting the electromagnetic pulse cell may cooperate with one of the scrap conveyors removing waste from the draw press cell.

[0027] After the laser trim operation or electromagnetic pulse operation is complete, the material handling robot may move the panel workpieces to separate inner panel and outer panel automated adjustable in-process racks for temporary storage until the inner and outer panels are sent to a flex assembly subsystem. The system does not involve trucking of inner and outer panels from the stamping location (i.e., location of the draw press), either by human operated lift trucks or automated guided vehicles (AGV's). Rather, the stamping operation is tied directly to the assembly operation, with the parts being passed between operations by material handling robots. In the flexible ("flex") assembly subsystem, the inner and outer panels are assembled into finished end products such as automotive closure panel assemblies.

[0028] A material handling robot unloads finished assemblies from the flex assembly subsystem and moves them to an inspection subsystem such as a white light inspection cell. The white light inspection cell includes one or more flexible nesting stands having a breaking feature. The material handling robot is used as the servo positioning unit to move the nesting features of the nesting stands into position for the various sizes and shapes of panel assemblies being run through the inspection subsystem. The nesting stands hold the panel assemblies in position for the white light inspection operation. The white light inspection cell also includes a white light inspection robot to which a camera is mounted and programmed to collect inspection data for all products being run through the system. A turntable oscillates the panel
After the inspection operation is complete, the material handling robot moves the finished assemblies to a final assembly part rack. The material handling robot performs the auto racking function.

With reference to FIG. 1, in a first specific embodiment, a manufacturing process in accordance with the invention includes an integrated system 10 having a forming subsystem 11 including one stamping draw press 12 that is dedicated for all products produced by the system. This embodiment is intended for low volume operation. A blank panel washer and feeder 14 cleans sheet metal panel blanks (e.g., aluminum or steel sheet panels) and feeds them into the forming subsystem 11. Part flow through the system 10 is generally illustrated by bold arrows. A first robotic material conveyor such as a material handling robot 16 (robot #1) moves the sheet metal blanks from the feeder 14 to the stamping draw press 12. Two die changers such as rotary die changers 18 allow for the changing of the dies 20 used in the stamping draw press 18 to allow for the forming of inner and outer panels by the draw press as well as for the forming of various sizes and shapes of panels. Each rotary die changer 18 handles multiple die sets that are coordinated to the height of a press bed of the draw press. For example, one die set includes the die 20 labeled “Op 10 Outer” and the die 20 labeled “Op 10 Inner,” another die set includes the die 20 labeled “Op 20 Outer” and the die 20 labeled “Op 20 Inner,” another die set includes the die 20 labeled “Op 30 Outer” and the die 20 labeled “Op 30 Inner,” and another die set includes the die 20 labeled “Op 40 Outer” and the die 20 labeled “Op 40 Inner.” Each rotary die changer 18 may accommodate from one to six dies 20 depending on the forming requirements of the panel(s). For example, in the embodiment shown, the two rotary die changers 18 hold eight total stamping dies 20, four of which are inner panel stamping dies and four of which are outer panel stamping dies. The die sets (i.e., a set of die for a fabrication operation) are split between the two rotary die changers 18 to reduce die change time. In other words, as one of the rotary die changers 18 removes a die 20 from the draw press 12, the other rotary die changer 18 can load a die 20 onto the draw press. The rotary motion of the rotary die changers 18 may occur during the stamping operations.

Between stamping operations, the first material handling robot 16 (robot #1) and a second material handling robot 16 (robot #2) move in-process workpieces from the draw press 12 to one of two automated adjustable in-process racks 22. The automated adjustable in-process racks 22 can be positioned for various sizes and shapes of panels, even if the shape changes in process from one die operation to another die operation. Two scrap conveyors 24 remove stamping operation offal (waste pieces generated from operations on the panels) from the draw press 12. The scrap conveyors 24 may be located on opposite sides of the draw press 12. After the draw operation is completed, a cushion may be optionally employed. The stamping draw press 12 may be used for some or all of the stamping operations for both the inner panels and outer panels including but not limited to re-strike, trim, pierce, and flanging.

A third material handling robot 16 (robot #3) transports the formed inner and outer panels from the draw press 12 to a laser trim cell 26 that is also included in the forming subsystem 11. The laser trim cell 26 includes two flexible nesting stands 28 having a breaking feature. The material handling robot 16 (robot #3) is used as the servo positioning unit to move the nesting features of the nesting stands 28 into position for the various sizes and shapes of panel workpieces being run through the system 10. The nesting stands 28 hold the panel workpieces in position for laser trim operations. The laser trim cell also includes a laser trim robot 30 (robot #4) that performs the laser trim operations and thereby functions as a laser trim apparatus. The laser trim robot 30 also handles scrap from the laser trim operation or optionally from trim or piercing operations of the stamping dies 20 of the draw press 12 depending upon the die process used. A turntable 38 oscillates the panel nesting stands 28 into and out of the laser trim robot work envelope (i.e., the maximum reach of the robot). A scrap conveyor 24 removes laser trim offal from the laser trim cell. The scrap conveyor 24 exiting the laser trim cell cooperates with one of the scrap conveyors 24 removing waste from the draw press 12. The laser trim cell may be shielded around its periphery by an enclosure.

After the laser trim operation is complete, the material handling robot 16 (robot #5) moves the panel workpieces to either an inner panel automated adjustable in-process rack 22 (“Inner Rack”) or an outer panel automated adjustable in-process rack 22 (“Outer Rack”) for temporary storage until the inner and outer panels are sent to a flex assembly subsystem 32. The inner panels are placed on the inner panel rack and the outer panels are placed on the outer panel rack. Inner and outer panels are sent from the inner panel rack and the outer panel rack to the assembly subsystem 32 in which they are assembled into finished end products such as automotive closure panel assemblies.

A fourth material handling robot 16 (robot #5) unloads assembled panels from the assembly subsystem 32 and moves them to an inspection subsystem 34 such as a white light inspection cell. The white light inspection cell 34 includes a flexible nesting stands 28 having a breaking feature. The material handling robot 16 (robot #5) is used as the servo positioning unit to move the nesting features of the nesting stands 28 into position for the various sizes and shapes of panel assemblies being run through the inspection cell 34. The nesting stands 28 hold the panel assemblies in position for the white light inspection operations. The white light inspection cell 34 also includes a white light inspection robot 36 (robot #6) to which a camera is mounted and programmed to collect inspection data for all products being run through the system. A turntable 38 oscillates the panel nest stands into and out of the white light inspection robot work envelope.

After the inspection operation is complete, the material handling robot 16 (robot #5) transfers the finished assemblies to a final assembly part rack 40. The material handling robot 16 (robot #5) performs the auto racking function.

Each of the material handling robots 16 (robot #1, robot #2, robot #3, and robot #5) has a change out end-effector that allows the robot to handle the various styles (size and shape) of panels being run through the system 10.

With reference to FIG. 2, in a second embodiment 110, the first embodiment is modified to include a roller flanging cell 142 that performs flanging of the outer panels. This reduces the number of die sets necessary for the fabrication process. The second embodiment 110, similar to...
the first embodiment, utilizes a single stamping draw press for all products manufactured by the system and is intended for low volume production.

In this embodiment, a blank panel washer and feeder cleans sheet metal panel blanks and feeds them into a forming subsystem. A first material handling robot moves the sheet metal blanks from the feeder to the stamping draw press. Two rotary die changers allow for the changing of dies used in the stamping draw press to allow for the forming of inner and outer panels by the draw press as well as for the forming of various sizes and shapes of panels. Each rotary die changer handles multiple die sets that are coordinated to the height of a press bed of the draw press. Each rotary die changer may accommodate from one to six dies depending on the forming requirements of the panels. For example, in the embodiment shown, the two rotary die changers hold six total stamping dies, three of which are inner panel stamping dies and three of which are outer panel stamping dies. The die sets (i.e., a set of die for a fabrication operation) are split between the two rotary die changers to reduce die change time. In other words, as one of the rotary die changers removes a die from the draw press, the other rotary die changer can load a die onto the draw press. The rotary motion of the rotary die changers may occur during the stamping operations. In this embodiment, the die set that performs the flanging operation has been removed because the flanging operation is performed by the roller flanging cell as described in more detail below.

Between stamping operations, the first material handling robot and a second material handling robot move in-process workpieces from the draw press to one of two automated adjustable in-process racks. The automated adjustable in-process racks can be positioned for various sizes and shapes of panels, even if the shape changes in process from one die operation to another die operation. Two scrap conveyors remove stamping operation offal from the draw press. The scrap conveyors may be located on opposite sides of the draw press. After the draw operation is completed, a cushion may be optionally deployed. The stamping draw press is used for the stamping operations of both the inner panels and outer panels, including but not limited to re-strike, trim, and pierce.

A third material handling robot transports the formed inner and outer panels from the draw press to a laser trim cell. The laser trim cell includes two flexible nesting stands having a breaking feature. The material handling robot is used as the servo positioning unit to move the nesting features of the nesting stands into position for the various sizes and shapes of panel workpieces being run through the system. The nesting stands hold the panel workpieces in position for laser trim operations. The laser trim cell includes a laser trim robot and a laser trim robot. The laser trim robot handles scrap from the laser trim operation or optionally from trim or piercing operations of the stamping dies of the draw press depending upon the die process used. A turntable oscillates the panel nest stands into and out of the laser trim robot work envelope. A scrap conveyor removes laser trim offal from the laser trim cell. The scrap conveyor exiting the laser trim cell cooperates with one of the scrap conveyors removing waste from the draw press. The laser trim cell is shielded around its periphery by an enclosure.

After the laser trim operation is complete, the material handling robot moves the panel workpieces to either an inner panel automated adjustable in-process rack or an outer panel automated adjustable in-process rack for temporary storage. The inner panels are placed on the inner panel rack and the outer panels are placed on the outer panel rack. Inner panels are sent from the inner panel rack to a flex assembly subsystem in which they are assembled with outer panels into finished end products such as automotive closure panel assemblies.

Prior to being sent to the flex assembly subsystem, the outer panels are transferred to a roller hemming cell by a fourth material handling robot. The roller flanging cell includes a plurality of roller flanging anvils. The roller flanging anvils may be auto-changed to accommodate for various sizes and shapes of panels. The roller flanging cell also includes a plurality of roller flanging robots that comprise a roller flanging apparatus. In the embodiment shown, the roller flanging cell includes three roller flanging robots that have roller heads that are used to flange the outer panels. When the roller flanging operation is complete, the fourth material handling robot transfers the outer panels to the flex assembly subsystem.

In this embodiment, the flex assembly subsystem includes an inner assembly subsystem and an outer assembly subsystem. The inner panels are passed to the inner assembly subsystem and the outer panels are passed to the outer assembly subsystem. From the inner and outer assembly subsystems, the inner and outer panels are sent to a roller hemming cell within the flex assembly subsystem. The roller hemming cell includes a plurality of interchangeable anvils and a plurality of roller hemming robots that comprise a roller hemming apparatus. In the roller hemming cell, the inner and outer panels are robotically roller hemmed together. The hemmed panels are then passed to a final assembly subsystem within the flex assembly subsystem.

A fifth material handling robot unloads finished assemblies from the flex assembly subsystem and moves them to an inspection subsystem such as a white light inspection cell. The white light inspection cell includes two flexible nesting stands having a breaking feature. The material handling robot is used as the servo positioning unit to move the nesting features of the nesting stands into position for the various sizes and shapes of panel assemblies being run through the inspection cell. The nesting stands hold the panel assemblies in position for white light inspection operations. The white light inspection cell also includes a white light inspection robot to which a camera is mounted and programmed to collect inspection data for all products being run through the system. A turntable oscillates the panel nest stands into and out of the white light inspection robot work envelope.

After the inspection operation is complete, the fifth material handling robot transfers the finished
assemblies to a final assembly part rack 140. The material handling robot 116 performs the auto racking function.

[0046] Each of the material handling robots 116 (robot #1, robot #2, robot #3, robot #5, and robot #9) has a change out end-effector that allows the robot to handle the various styles (size and shape) of panels being run through the system 110.

[0047] With reference to FIG. 3, in a third embodiment 210 a manufacturing process in accordance with the invention includes an integrated system having two stamping draw presses 212 that are dedicated for all products manufactured by the system. This embodiment is intended for midrange volume operation. The third embodiment 210 is otherwise similar to the first embodiment 10.

[0048] Two blank panel feeders 214 feed sheet metal panel blanks into a forming subsystem 211. A first material handling robot 216 (robot #1) moves sheet metal blanks from one of the feeders 214 to a first stamping draw press 212 and a second material handling robot 216 (robot #2) moves sheet metal blanks from the other feeder 214 to a second stamping draw press 212. Each of the draw presses 212 may be dedicated to forming either inner panels or outer panels. For example, the first draw press may be used to form inner panels while the second draw press may be used to form outer panels. The blank panel feeder 214 for the outer panels also includes a washer that cleans the outer sheet metal blanks prior to the blanks being fed to the draw press 212.

The inner sheet metal blanks are not cleaned.

[0049] Two rotary die changers 218 allow for the changing of the dies 220 used by the draw presses 212 to allow for the forming of inner and outer panels by the draw presses as well as for the forming of various sizes and shapes of panels. Each rotary die changer 218 handles multiple die sets that are coordinated to the height of a press bed of the draw press. Each rotary die changer 218 may accommodate from one to six dies depending on the forming requirements of the panels. For example, in the embodiment shown, the two rotary die changers 218 hold eight total stamping dies 220, four of which are inner panel stamping dies and four of which are outer panel stamping dies. The die sets (i.e., a set of die for a fabrication operation) are split between the two rotary die changers 218, and each rotary die changer holds either the inner dies or the outer dies. Therefore, each of the draw presses 212 is dedicated for forming either inner panels or outer panels.

[0050] Between stamping operations, the first and second material handling robots 216 (robot #1 and robot #2) along with a third material handling robot 216 (robot #3) and a fourth material handling robot 216 (robot #4) move in-process workpieces from the draw presses 212 to one of four servo in-process racks 222. The servo is used to position the racks for various sizes and shapes of panels, even if the shape changes in process from one die operation to another die operation. Two scrap conveyors 224 remove stamping operation offal away from the draw presses 212. The scrap conveyors 224 may be located on opposite sides of the draw presses 212. After the draw operation is completed, a cushion may be optionally employed. The draw presses 212 may be used for some or all of the stamping operations for both the inner panels and outer panels including but not limited to re-strike, trim, Pierce, and flanging.

[0051] A fifth material handling robot 216 (robot #5) and a sixth material handling robot 216 (robot #6) transport the formed inner and outer panels from the draw presses 212 to a laser trim cell 226. The laser trim cell 226 includes two flexible nesting stands 228 having a breaking feature. The fifth material handling robot 216 (robot #5) is used as the servo positioning unit to move the nesting features of the nesting stands 228 into position for the various sizes and shapes of panel workpieces being run through the system 210. The nesting stands 228 hold the panel workpieces in position for laser trim operations. The laser trim cell 226 also includes a laser trim robot 230 (robot #7) that performs the laser trim operations. The laser trim robot 230 also handles scrap from the laser trim operation or optionally from trim or piercing operations of the stamping dies of the draw press 212 depending upon the die process used. A turntable 238 oscillates the panel nest stands 228 into and out of the laser trim robot work envelope. A scrap conveyor 224 removes laser trim offal from the laser trim cell 226. The scrap conveyor 224 exiting the laser trim cell 226 cooperates with one of the scrap conveyors 224 removing waste from the draw press 212. The laser trim cell 226 is shielded around its periphery by an enclosure.

[0052] After the laser trim operation is complete, the fifth material handling robot 216 (robot #5) and sixth material handling robot 216 (robot #6) move the panel workpieces to a flex assembly subsystem 232. In the flex assembly subsystem 232, the inner and outer panels are assembled into finished end products such as automotive closure panel assemblies.

[0053] A seventh material handling robot 216 (robot #8) unloads finished assemblies from the flex assembly subsystem 232 and moves them to an inspection subsystem 234 such as a white light inspection cell. The white light inspection cell 234 includes two flexible nesting stands 228 having a breaking feature. The seventh material handling robot 216 (robot #8) is used as the servo positioning unit to move the nesting features of the nesting stands 228 into position for the various sizes and shapes of panel assemblies being run through the inspection subsystem 234. The nesting stands 228 hold the panel assemblies in position for white light inspection operations. The white light inspection cell 234 also includes a white light inspection robot 236 (robot #9) to which a camera is mounted and programmed to collect inspection data for all products being run through the system 210. A turntable 238 oscillates the panel nest stands 228 into and out of the white light inspection robot work envelope.

[0054] After the inspection operation is complete, the seventh material handling robot 216 (robot #8) transfers the finished assemblies to a final assembly part rack 240. The material handling robot 216 (robot #8) performs the auto racking function.

[0055] Each of the material handling robots 216 (robot #1, robot #2, robot #3, robot #4, robot #5, robot #6, and robot #8) has a change out end-effector that allows the robot to handle the various styles (size and shape) of panels being run through the system 210.

[0056] With reference to FIG. 4, in a fourth embodiment 310, the third embodiment 210 is modified to include a roller flanging cell 342 that performs flanging of the outer panels. This reduces the number of die sets necessary for the fabrication process. The fourth embodiment 310, similar to the third embodiment 210, utilizes two stamping draw presses 312 for all products manufactured by the system and is intended for midrange volume production.

[0057] Two blank panel feeders 314 feed sheet metal panel blanks into a forming subsystem 311 including the two draw presses 312. A first material handling robot 316 (robot #1)
moves sheet metal blanks from one of the feeders 314 to the first stamping draw press 312 and a second material handling robot 316 (robot #2) moves sheet metal blanks from the other feeder 314 to the second stamping draw press 312. Each of the draw presses 312 may be dedicated to forming either inner panels or outer panels. For example, the first draw press 312 may be used to form inner panels while the second draw press 312 may be used to form outer panels. The blank panel feeder 314 for the outer panels also includes a washer that cleans the outer sheet metal blanks prior to the blanks being fed to the draw press 312. The inner sheet metal blanks are not cleaned.

[0058] Two rotary die changers 318 allow for the changing of the dies 320 used by the draw presses 312 to allow for the forming of inner and outer panels by the draw presses as well as for the forming of various sizes and shapes of panels. Each rotary die changer 318 handles multiple die sets that are coordinated to the height of a press bed of the draw press 312. Each rotary die changer 318 may accommodate from one to six dies 320 depending on the forming requirements of the panels. For example, in the embodiment shown, the two rotary die changers 318 hold eight total stamping dies 320, four of which are inner panel stamping dies and four of which are outer panel stamping dies. The die sets (i.e., a set of die for a fabrication operation) are split between the two rotary die changers 318, and each rotary die changer holds either the inner dies or the outer dies. Therefore, each of the draw presses 312 is dedicated for forming either inner panels or outer panels.

[0059] Between stamping operations, the first and second material handling robots 316 (robot #1 and robot #2) along with a third material handling robot 316 (robot #3) and a fourth material handling robot 316 (robot #4) move in-process workpieces from the draw presses 312 to one of four servo in-process racks 322. The servo is used to position the racks for various sizes and shapes of panels, even if the shape changes in process from one die operation to another die operation. Two scrap conveyors 324 remove stamping operation offal away from the draw presses 312. The scrap conveyors 324 may be located on opposite sides of the draw presses 312. After the draw operation is completed, a cushion may be optionally employed. The draw presses 312 may be used for some or all of the stamping operations for both the inner panels and outer panels including but not limited to re-strike, trim, pierce, and flanging.

[0060] A fifth material handling robot 316 (robot #5) transports the formed inner panels from the draw press 312 to a laser trim cell 326. The laser trim cell 326 includes two flexible nesting stands 328 having a breaking feature. The fifth material handling robot 316 (robot #5) is used to position the unit to move the nesting features of the nesting stands 328 into position for the various sizes and shapes of panel workpieces being run through the system 310. The nesting stands 328 hold the panel workpieces in position for the laser trim operations. The laser trim cell 326 also includes a laser trim robot 330 (robot #7) that performs the laser trim operations. The laser trim robot 330 also handles scraps from the laser trim operation or optionally from trim or piercing operations of the stamping dies of the draw press 312 depending upon the die process used. A turntable 338 oscillates the panel nest stands 328 into and out of the laser trim robot work envelope. A scrap conveyor 324 removes laser trim offal from the laser trim cell 326. The scrap conveyor 324 exits the laser trim cell 326 cooperates with one of the scrap conveyors 324 removing waste from the draw press 312. The laser trim cell 326 is shielded around its periphery by an enclosure.

[0061] After the laser trim operation is complete, the fifth material handling robot 316 (robot #5) moves the panel workpieces to an inner panel automated adjustable in-process rack 322 for temporary storage. Inner panels are sent from the inner panel rack to a flex assembly subsystem 332 in which they are assembled with outer panels into finished end products such as automotive closure panel assemblies.

[0062] Prior to being sent to the flex assembly subsystem 332, the outer panels may be transferred to a roller flanging cell 342 by a sixth material handling robot 316 (robot #6). The roller flanging cell 342 includes a plurality of roller flanging anvils 344. The roller flanging anvils 344 may be auto-changed to accommodate for various sizes and shapes of panels. The roller flanging cell 342 also includes a plurality of roller flanging robots 346 that comprise a roller hemming apparatus. In the embodiment shown, the roller flanging cell 342 includes three roller flanging robots 346 (robot #7, robot #9, and robot #10). The roller flanging robots 346 each have roller heads that are used to flange (e.g., pre-hem flange) the outer panels over one of the anvils 344. When the roller flanging operation is complete, the sixth material handling robot 316 (robot #6) transfers the outer panels to the assembly subsystem 332.

[0063] In this embodiment, the flex assembly subsystem 332 includes an inner assembly subsystem and an outer assembly subsystem. The inner panels are passed to the inner assembly subsystem and the outer panels are passed to the outer assembly subsystem. From the inner and outer assembly subsystems, the inner and outer panels are sent to a roller hemming cell 348 within the assembly subsystem 332. The roller hemming cell 348 includes a plurality of interchangeable anvils 350 and a plurality of roller hemming robots 352. In the roller hemming cell 348, the inner and outer panels are robotically roller hemmed together. The hemmed panels are then passed to a final assembly subsystem within the assembly subsystem 332.

[0064] A seventh material handling robot 316 (robot #11) unloads finished assemblies from the assembly subsystem 332 and moves them to an inspection subsystem 334 such as a white light inspection cell. The white light inspection cell 334 includes two flexible nesting stands 328 having a breaking feature. The seventh material handling robot 316 (robot #11) is used as the servo positioning unit to move the nesting features of the nesting stands 328 into position for the various sizes and shapes of panel assemblies being run through the inspection subsystem 334. The nesting stands 328 hold the panel assemblies in position the white light inspection operations. The white light inspection cell 334 also includes a white light inspection robot 336 (robot #12) to which a camera is mounted and programmed to collect inspection data for all products being run through the system 310. A turntable 338 oscillates the panel nest stands 328 into and out of the white light inspection robot work envelope.

[0065] After the inspection operation is complete, the seventh material handling robot 316 (robot #11) transfers the finished assemblies to a final assembly part rack 340. The material handling robot 316 (robot #11) performs the auto-necking function.

[0066] Each of the material handling robots 316 (robot #1, robot #2, robot #3, robot #4, robot #5, robot #6, and robot
has a change out end-effector that allows the robot to handle the various styles (size and shape) of panels being run through the system 310.

[0067] With reference to FIG. 5, in a fifth embodiment 410, the second embodiment 110 is modified to substitute an electromagnetic pulse cell 454 (EMP Outer Cell) for the roller flanging cell that performs flanging of the outer panels in the second embodiment. In the fifth embodiment 410, the “EMP Outer Cell” 454 performs flanging operations on outer panels. Also, in the fifth embodiment 410, another electromagnetic pulse cell 456 (EMP Inner Cell) is substituted for the laser trim cell of the second embodiment 110. The “EMP Inner Cell” 456 of the fifth embodiment 410 performs trim, re-strike, and/or pierce operations on inner panels. The two electromagnetic pulse operation cells 454, 456 reduce the die trim, re-strike, flange, and pierce operations and can eliminate a die from the stamping process that would be used to perform these operations. The fifth embodiment 410, similar to the second embodiment 110, utilizes a single stamping press 412 for all products manufactured by the system and is intended for low volume production.

[0068] In this embodiment, a blank panel washer and feeder 414 cleans sheet metal panel blanks and feeds them into a forming subsystem 411. A first material handling robot 416 (robot #1) moves the sheet metal blanks from the feeder to the stamping draw press 412 in the forming subsystem 411. Two rotary die changers 418 allow for the changing of the dies 420 used in the stamping draw press 412 to allow for the forming of inner and outer panels by the draw press as well as for the forming of various sizes and shapes of panels. Each rotary die changer 418 handles multiple die sets that are coordinated to the height of a press bed of the draw press 412. Each rotary die changer 418 may accommodate from one to six dies 420 depending on the forming requirements of the panels. For example, in the embodiment shown, the two rotary die changers 418 hold six total stamping dies 420, three of which are inner panel stamping dies and three of which are outer panel stamping dies. The die sets (i.e., a set of die for a fabrication operation) are split between the two rotary die changers 418 to reduce die change time. In other words, as one of the rotary die changers 418 removes a die from the draw press 412, the other rotary die changer 418 can load a die onto the draw press. The rotary motion of the rotary die changers 418 may occur during the stamping operations. In this embodiment, the die set that performs the flanging operation has been removed because the flanging operation is performed by the electromagnetic pulse cell 454 as described in more detail below.

[0069] Between stamping operations, the first material handling robot 416 (robot #1) and a second material handling robot 416 (robot #2) move in-process workpieces from the draw press 412 to one of two automated adjustable in-process racks 422. The automated adjustable in-process racks 422 can be positioned for various sizes and shapes of panels, even if the shape changes in process from one die operation to another die operation. Two scrap conveyors 424 remove stamping operation offal from the draw press 412. The scrap conveyors 424 may be located on opposite sides of the draw press 412. After the draw operation is completed, a cushion may be optionally employed. The stamping draw press 412 is used for the stamping operations of both the inner panels and outer panels, including but not limited to stamp, re-strike, trim, and pierce, although some of these operations may be performed by the electromagnetic pulse cells 454, 456.

[0070] A third material handling robot 416 (robot #3) transports the formed inner panels from the draw press 412 to the electromagnetic pulse cell 456. The electromagnetic pulse cell 456 includes a plurality of female anvils 458 that inner panels are nested in. Each anvil 458 allows for the production of model specific holes, flange conditions, or trim operations, thereby reducing full stamping die sets. The anvils 458 in the electromagnetic pulse cell 456 may be interchanged by an anvil change out track that may be either power driven or robot driven. The electromagnetic pulse cell 456 also includes an electromagnetic pulse robot 460 (robot #4) that carries an electromagnetic pulse apparatus 462 and is programmed for model specific electromagnetic pulse operations. Alternatively, the electromagnetic pulse apparatus may be stationarily mounted, such as on a pedestal stand, and workpieces may be positioned relative to the stationary electromagnetic pulse apparatus. A scrap conveyor 424 removes waste pieces from the electromagnetic pulse cell 456. The scrap conveyor 424 exiting the electromagnetic pulse cell 456 cooperates with one of the scrap conveyors 424 removing waste from the draw press 412.

[0071] After the electromagnetic pulse operation(s) is complete, the material handling robot 416 (robot #3) moves the panel workpieces to an inner panel automated adjustable in-process rack 422. Inner panels are sent from the inner panel in-process rack 422 to a flex assembly subsystem 432 in which they are assembled with outer panels into finished end products such as automotive closure panel assemblies.

[0072] Prior to being sent to the flex assembly subsystem 432, the outer panels are transferred by the third material handling robot 416 (robot #3) from the draw press 412 to an outer panel automated adjustable in-process rack 422 for temporary storage. A fourth material handling robot 416 (robot #5) then transfers the outer panels to the electromagnetic pulse cell 454. The electromagnetic pulse cell 454 includes a plurality of flanging anvils 464. The flanging anvils 464 may be auto-changed to accommodate for various sizes and shapes of panels. The electromagnetic pulse cell 454 may include an anvil change out track for exchanging the anvils 464. The change out track may be power driven or robot driven. The electromagnetic pulse cell 454 also may include an electromagnetic pulse robot 460 (robot #1). The electromagnetic pulse robot 460 includes an electromagnetic pulse apparatus 62 that is programmed for model specific operations. When the electromagnetic pulse flanging operation(s) is complete, the fourth material handling robot 416 (robot #5) transfers the outer panels to the flex assembly subsystem 432.

[0073] In this embodiment, the flex assembly subsystem 432 includes an inner assembly subsystem and an outer assembly subsystem. The inner panels are passed to the inner assembly subsystem and the outer panels are passed to the outer assembly subsystems. From the inner and outer assembly subsystems, the inner and outer panels are sent to a roller hemming cell 448 within the assembly subsystem 432. The roller hemming cell 448 includes a plurality of interchangeable anvils 450 and a plurality of roller hemming robots 452. In the roller hemming cell 448, the inner and outer panels are robotically roller hemmed together. The hemmed panels are then passed to a final assembly subsystem within the assembly subsystem 432.
A fifth material handling robot 416 (robot #9) unloads finished assemblies from the assembly subsystem 432 and moves them to an inspection subsystem 434 such as a white light inspection cell. The white light inspection cell 434 includes two flexible nesting stands 428 having a breaking feature. The material handling robot 416 (robot #9) is used as the servo positioning unit to move the nesting features of the nesting stands 428 into position for the various sizes and shapes of panel assemblies being run through the inspection subsystem 434. The nesting stands 428 hold the panel assemblies in position for white light inspection operations. The white light inspection cell 434 also includes a white light inspection robot 436 (robot #10) to which a camera is mounted and programmed to collect inspection data for all products being run through the system 410. A turntable 438 oscillates the panel nest stands 428 into and out of the white light inspection robot work envelope.

After the inspection operation is complete, the fifth material handling robot 416 (robot #9) transfers the finished assemblies to a final assembly part rack 440. The material handling robot 416 (robot #9) performs the auto racking function.

Each of the material handling robots 416 (robot #1, robot #2, robot #3, robot #8, and robot #9) has a change out end-effector that allows the robot to handle the various styles (size and shape) of panels being run through the system 410.

With reference to FIG. 6, in a sixth embodiment 510, the fourth embodiment 310 is modified to substitute an electromagnetic pulse (EMP) cell 554 for the roller flanging cell 342 that performs flanging of the outer panels in the fourth embodiment. Also, an electromagnetic pulse (EMP) cell 556 is substituted for the laser trim cell 426 of the fourth embodiment. This electromagnetic pulse cell 556 performs trim, re-strike, flange, and/or pierce operations on inner panels. The two electromagnetic pulse operation cells 554, 556 reduce the die trim, re-strike, flange, and pierce operations and can eliminate a die from the stamping process that would be used to perform these operations. The sixth embodiment 610, similar to the fourth embodiment 410, utilizes two stamping draw presses 512 for all products manufactured by the system and is intended for midrange volume production.

Two blank panel feeders 514 feed sheet metal panel blanks into a forming subsystem 511 including the draw presses 512. A first material handling robot 516 (robot #1) moves sheet metal blanks from one of the feeders 514 to one of the stamping draw presses 512 and a second material handling robot 516 (robot #2) moves sheet metal blanks from the other feeder 514 to the other stamping draw press 512. Each of the draw presses 512 may be dedicated to forming either inner panels or outer panels. For example, the first draw press may be used to form inner panels while the second draw press may be used to form outer panels. The blank panel feeder 514 for the outer panels also includes a washer that cleans the outer sheet metal blanks prior to the blanks being fed to the draw press 512. The inner sheet metal blanks are not cleaned.

Two rotary die changers 518 allow for the changing of the dies 520 used by the draw presses 512 to allow for the forming of inner and outer panels by the draw presses as well as for the forming of various sizes and shapes of panels. Each rotary die changer 518 handles multiple die sets that are coordinated to the height of a press bed of the draw press 512. Each rotary die changer 518 may accommodate from one to six dies 520 depending on the forming requirements of the panels. For example, in the embodiment shown, the two rotary die changers 518 hold eight total stamping dies 520, four of which are inner panel stamping dies and four of which are outer panel stamping dies. The die sets (i.e., a set of die for a fabrication operation) are split between the two rotary die changers 518, and each rotary die changer holds either the inner dies or the outer dies. Therefore, each of the draw presses 512 is dedicated for forming either inner panels or outer panels.

Between stamping operations, the first and second material handling robots 516 (robot #1 and robot #2) along with a third material handling robot 516 (robot #3) and a fourth material handling robot 516 (robot #4) move in-process workpieces from the draw presses 512 to one of four servo in-process racks 522. The servo is used to position the racks 522 for various sizes and shapes of panels, even if the shape changes in process from one die operation to another die operation. Two scrap conveyors 524 remove stamping operation offal away from the draw presses 512. The scrap conveyors 524 may be located on opposite sides of the draw presses 512. After the draw operation is completed, a cushion may be optionally employed. In this embodiment 510, the draw presses 512 may be used for any of the stamping operations for both the inner panels and outer panels including but not limited to re-strike, trim, pierce, and flanging, although some of these operations may be performed by the electromagnetic pulse cells 554, 556.

A fifth material handling robot 516 (robot #5) transports the formed inner panels from the draw press 512 to the electromagnetic pulse cell 556. The electromagnetic pulse cell 556 includes a plurality of female anvils 558 that inner panels are nested in. Each anvil 558 is configured to accommodate for various sizes and shapes of panels. The electromagnetic pulse cell 556 also includes an electromagnetic pulse robot 560 (robot #7) that carries an electromagnetic pulse apparatus 562 and is programmed for model specific electromagnetic pulse operations. Alternatively, the electromagnetic pulse apparatus may be stationarily mounted, such as on a pedestal stand, and workpieces may be positioned relative to the stationary electromagnetic pulse apparatus. A scrap conveyor 524 removes waste pieces from the electromagnetic pulse cell 556. The scrap conveyor 524 exiting the electromagnetic pulse cell 556 cooperates with one of the scrap conveyors 524 removing waste from the draw presses 512.

After the electromagnetic pulse operation is complete, the fifth material handling robot 516 (robot #5) moves the panel workpieces to an inner panel automated adjustable in-process rack 522 for temporary storage. Inner panels are sent from the inner panel rack to the flex assembly subsystem 332 in which they are assembled with outer panels into finished end products such as automotive closure panel assemblies.

Prior to being sent to the flex assembly system 432, the outer panels may be transferred to the separate electromagnetic pulse cell 554 by a sixth material handling robot 516 (robot #6). The second electromagnetic pulse cell 554 includes a plurality of flanging anvils 564. The flanging anvils 564 may be auto-changed to accommodate for various sizes and shapes of panels. The electromagnetic pulse cell
554 may include an anvil change out track for exchanging the anvils 564. The change out track may be power driven or robot driven. The electromagnetic pulse cell 554 also may include an electromagnetic pulse robot (robot #8) 560. The electromagnetic pulse robot 560 has an electromagnetic pulse apparatus 562 that is programmed for model specific operations. When the electromagnetic pulse flanging operation(s) is complete, the sixth material handling robot 516 (robot #6) transfers the outer panels to the flex assembly subsystem 532.

[0084] In this embodiment, the flex assembly subsystem 532 includes an inner assembly subsystem and an outer assembly subsystem. The inner panels are passed to the inner assembly subsystem and the outer panels are passed to the outer assembly subsystem. From the inner and outer assembly subsystem, the inner and outer panels are sent to a roller hemming cell 548 within the assembly subsystem 532. The roller hemming cell 548 includes a plurality of interchangeable anvils 550 and a plurality of roller hemming robots 552. In the roller hemming cell 548, the inner and outer panels arerobotically rolled hemmed together. The hemmed panels then are passed to a final assembly subsystem within the flex assembly subsystem 532.

[0085] A seventh material handling robot 516 (robot #9) unloads finished assemblies from the assembly subsystem 532 and moves them to an inspection subsystem 534 such as a white light inspection cell. The white light inspection cell 534 includes two flexible nesting stands 528 having a breaking feature. The seventh material handling robot 516 (robot #9) is used as the servo positioning unit to move the nesting features of the nesting stands 528 into position for the various sizes and shapes of panel assemblies being run through the inspection subsystem 534. The nesting stands 528 hold the panel assemblies in position for white light inspection operations. The white light inspection cell 534 also includes a white light inspection robot 536 (robot #12) to which a camera is mounted and programmed to collect inspection data for all products being run through the system. A turntable 538 oscillates the panel nests stands 528 into and out of the white light inspection robot work envelope.

[0086] After the inspection operation is complete, the seventh material handling robot 516 (robot #9) transfers the finished assemblies to a final assembly part rack 540. The material handling robot 516 (robot #9) performs the auto robot function.

[0087] Each of the material handling robots 516 (robot #1, robot #2, robot #3, robot #4, robot #5, robot #6, and robot #9) has a change out end-effector that allows the robot to handle the various styles (size and shape) of panels being run through the system 510.

[0088] Although the invention has been described by reference to specific embodiments, it should be understood that numerous changes may be made within the spirit and scope of the inventive concepts described. Accordingly, it is intended that the invention not be limited to the described embodiments, but that it have the full scope defined by the language of the following claims.

What is claimed is:

1. An integrated, automated, variable sheet metal forming and assembly system comprising:
   a plurality of robotic material conveyors;
   a forming subsystem including at least one sheet metal draw press apparatus;
   an assembly subsystem in series with and downstream from said forming subsystem, said assembly subsystem including a roller hemming apparatus; and
   an inspection subsystem in series with and downstream from said assembly subsystem;
   said plurality of robotic material conveyors being operable to convey assembly workpieces to and from said subsystems.

2. The integrated system of claim 1, wherein said forming subsystem includes at least one electromagnetic pulse apparatus in series with and downstream from said sheet metal draw press apparatus.

3. The integrated system of claim 2, including two electromagnetic pulse apparatuses in parallel with each other.

4. The integrated system of claim 1, wherein said forming subsystem includes a liser trim apparatus in series with and downstream from said sheet metal draw press apparatus.

5. The integrated system of claim 1, wherein said forming subsystem includes a roller hemming apparatus in series with and downstream from said sheet metal draw press apparatus.

6. The integrated system of claim 1, wherein said forming subsystem includes at least one die changer for changing dies of the draw press apparatus.

7. The integrated system of claim 6, wherein said forming subsystem includes two die changers and a plurality of die sets having a plurality of individual die, said individual die of each die set being divided amongst said two die changers.

8. The integrated system of claim 1, wherein said forming subsystem includes at least one scrap conveyor adjacent said draw press apparatus for conveying scrap metal pieces away from said forming subsystem.

9. The integrated system of claim 1, wherein said inspection subsystem includes a white light inspection apparatus.

10. The integrated system of claim 1, wherein said roller hemming apparatus of said assembly subsystem includes a plurality of interchangeable anvils.

11. A method for integrated sheet metal forming and assembly, the method comprising:
   providing a plurality of robotic material conveyors for conveying sheet metal workpieces;
   introducing a sheet metal blank to a forming subsystem including a sheet metal draw press apparatus to form a sheet metal panel;
   conveying said sheet metal panel to an assembly subsystem including a roller hemming apparatus;
   assembling a plurality of sheet metal panels in said assembly subsystem by using said roller hemming apparatus to form a hemmed sheet metal assembly; and
   conveying said sheet metal assembly to an inspection system for robotic inspection of said sheet metal assembly.

12. The method of claim 11, including the steps of:
   prior to conveying said sheet metal panel to said assembly subsystem, conveying said sheet metal panel to an electromagnetic pulse apparatus; and
   performing at least one of a trim operation, a re-strike operation, a flange operation, and a pierce operation on
said sheet metal panel using said electromagnetic pulse apparatus.

13. The method of claim 11, including the steps of:
   prior to conveying said sheet metal panel to said assembly subsystem, conveying said sheet metal panel to a laser trim apparatus; and
   performing robotic laser trimming of said sheet metal panel using said laser trim apparatus.

14. The method of claim 11, including the steps of:
   prior to conveying said sheet metal panel to said assembly subsystem, conveying said sheet metal panel to a roller hemming apparatus; and
   performing a hemming operation on said sheet metal panel using said roller hemming apparatus.

15. The method of claim 11, including the steps of:
   providing a plurality of die changers in said forming subsystem for changing dies of said draw press apparatus;
   providing a plurality of die sets including a plurality of individual die; and
   dividing said individual die of each die set amongst said plurality of die changers.