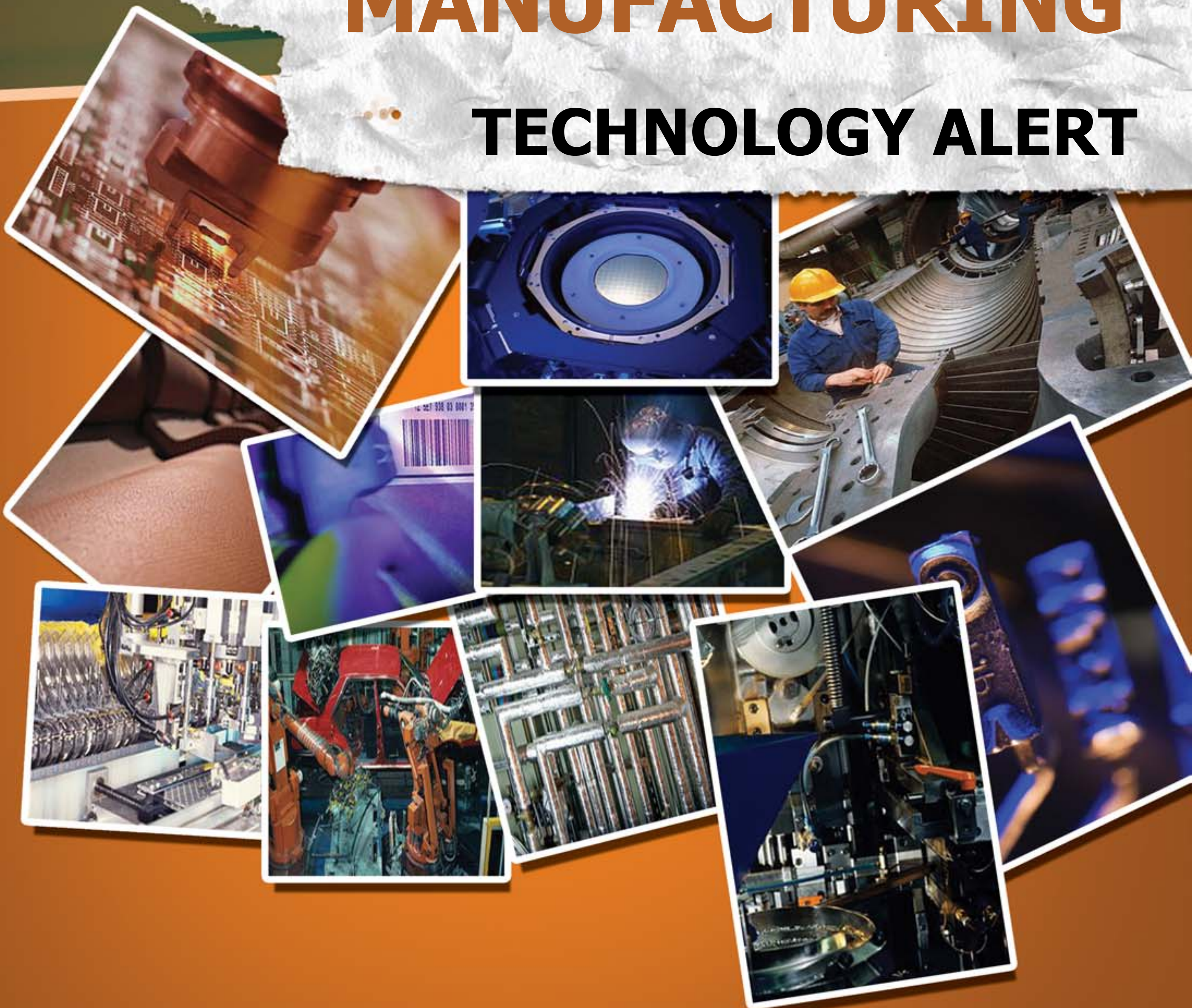
TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT



17th October 2014

1. ELECTRICAL DISCHARGE MACHINING PROGRESS

Electrical discharge machining (EDM) is a subtractive machining process (originally invented in the USSR during the early 1940s) that slowly removes hard metals on a work piece via spark erosion. When, for example, an internal threading tap (typically made of hardened high-speed steel, HSS) breaks off deep in a drilled hole, EDM may be the only way to remove it, without destroying the workpiece. *Technical Insights* staff, while learning the machining trade in machine shops (associated with an engineering education), witnessed such EDM rescue operations. The US was a slow adopter of EDM technology, which was more quickly embraced by Europeans, Japanese, not to mention the Soviets.

The layout of this process involves two electrodes--a workpiece electrode and a tool electrode--separated by a dielectric liquid (such as deionized water or hydrocarbon oil). When the tool electrode is moved close to the workpiece electrode, the dielectric will break down (actually forming an ionized column of dielectric), allowing current to flow, creating an electric arc or spark (as hot as 7,000-9,000 degrees C) that can quickly vaporize metals. Between the electrodes, there can be up to 1 million sparks per second, but 50,000/second is more common. Periodically, the dirty dielectric (loaded with micron-size particles of removed metal [electrode and work piece] over time) needs to be flushed out and replaced with fresh fluid. The dielectric fluid also cools the workpiece. The entire machining process can be executed by programmed CNC (computer numerical controller) technology, with no human intervention (thus, no human error).

The major variations of this machining method include: wire-cut EDM (a through-hole process which was developed in the 1960s-1970s), small hole drilling, and die-sinker EDM. The wire-cut involves a thin wire electrode (0.004-0.012 inch, typically brass) moved around by CNC-driven actuators on 4 independent axes. Deionized water is the preferred dielectric. The forward facing 180 degrees of wire does the cutting via sparking, leaving a kerf with no burrs through the conductive metal. This machining outcome can also be accomplished by laser cutting and water-jet cutting. Mechanical band sawing of a pattern is a poor substitute for CNC EDM wire cutting, which has accuracies of +/- 0.0001 inch. EDM can effectively cut plates as thick as 16.

The die-sinker EDM has electrodes that are mirror images of each other, and works well with complex 3D shapes. Oil is the preferred dielectric. Small hole drilling has a thin (0.010 to 0.118 inch) spinning hollow electrode with dielectric flushing through and around the tool electrode. A typical application is drilling of cooling holes into superalloy hot turbine blades, for both leading and trailing edges. In the opinion of *Technical Insights*, EDM is a niche manufacturing method, but has proved indispensable over the years, machining difficult metals (such as hard die materials) and delicate parts that can't withstand mechanical cutting forces.

Details: Larry Rinek, Senior Technology Consultant, Technical Insights, Frost & Sullivan, 331 E. Evelyn Avenue, suite 100, Mountain View, CA 94041, USA. Phone: 650-475-4521. E-mail: lrinek@frost.com. URL: www.ti.frost.com

2. DEVELOPMENTS IN AUTOMATED TAPE LAYERS FOR AEROSPACE COMPOSITES

For manufacturers of aerospace-grade resin-matrix composites, the automated tape layer ATL) has proved its worth in recent years. A gantry-type multi-axis CNC tape layer (as made by Cincinnati Machine) can lay-up 3D structures over conformal tooling, layer by layer in a highly repeatable manner, and much faster than a labor-intensive manual lay-up. Skilled technicians can place only 2.5 lb of material per hour, whereas ATLs can readily lay 100 lb/hr, drastically reducing man-hour requirements, thus sharply cutting direct manufacturing costs.

Tacky prepreg tape (75-300 mm wide) is typically made from woven PAN-type (poly acrylonitrile) high-strength carbon fibers (as made by Toray of Japan) infused with thermosetting epoxy resins. The spun polymer PAN fibers are first oxidized then undergo pyrolysis in the absence of air, carbonizing the material. After layup, the composite carbon fiber/resin assembly then receives a steam autoclave curing process, rendering a strong and light monolithic structure. ATLs can handle thermoset as well as thermoplastic impregnated tapes. Another technology related to ATL is automated fiber placement (AFP). Like ATL, AFP lays down resin-impregnated continuous fiber/resin tows in a manner that provides stiffness and strength where needed.

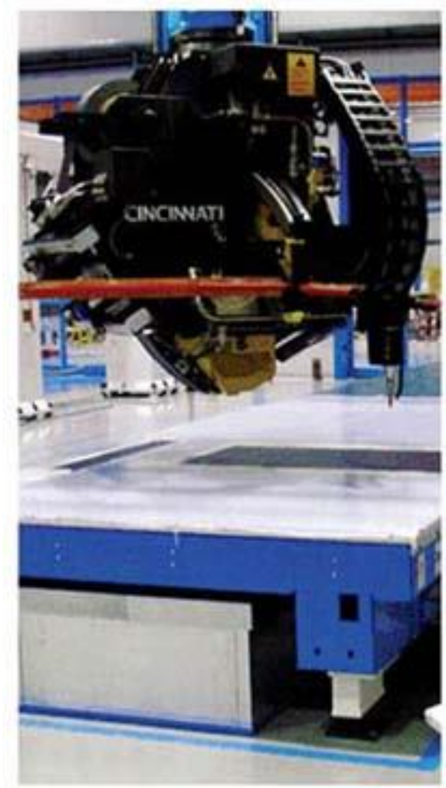


Exhibit 1 depicts the Cincinnati Machine ATL for aerospace structural applications.

Picture Credit: http://www.sme.org/MEMagazine/Article.aspx?id=27638&taxid=1411

Boeing is using at least 8 Cincinnati Machine ATLs for 777 and 787 wide-body airliner component manufacturing. The 787 Dreamliner is the most composite-intensive airliner ever built by Boeing. Spirit AeroSystems, a Boeing spin-off company in Wichita, Kansas, is also building carbon fiber/epoxy matrix composites for Boeing airliners (such as the 787) with ATLs. Alenia Aeronautica SpA in Italy operating ATLs for Boeing's 787 program.

The ATL has a multi-axis articulating robotic head that can be programmed to rapidly lay prepreg tape plies in different directions, providing multi-axis strength characteristics. Compacting is part of the tape laying process, so as to minimize vacuum consolidation (via vacuum tables), yielding favorable laminate compaction from the start. ATL suppliers include: Cincinnati Machine (Hebron, KY), and MTorres Group (Navarre also known as Navarra, Spain and Santa Ana, California), Forest-Line (Paris, France), Automated Dynamics (Schenectady, New York), and Accudyne Systems (Newark, Delaware). Cincinnati has large gantry contour ATLs with travel distances of 9.1 x 6.1 x 1.2 meters (X, Y, Z axes).

In the view of *Technical Insights*, ATL technology is here to stay and offers compelling economic benefits to fabricators of aero composite structures, even though these computerized and highly sophisticated gantry-type machines can cost composite manufacturers $2 million to $6 million each up front. They have elaborate electronic controls, multiple costly robotic actuators, complex prepreg tape handling and storage equipment as well as stiff supporting structures.

Details: Larry Rinek, Senior Technology Consultant, Technical Insights, Frost & Sullivan, 331 E. Evelyn Avenue, suite 100, Mountain View, CA 94041, USA. Phone: 650-475-4521. E-mail: lrinek@frost.com. URL: www.ti.frost.com

3. HIGH-SPEED STEEL TOOLS FOR MACHINING

Today, cost-effective hard and tough high speed steel (HSS) materials still dominate many machine shop tool markets, such as twist drills (or drill bits), taps, milling cutters, gear cutters (hobs), and more. They are sometimes hard-coated (as with physical vapor-deposited [PVD] TiN (tianium nitride) ceramic thin coatings, gold in color). However, bare HSS drills are found everywhere around the globe. How did this hard tool material get invented? Does HSS still have a future in metalworking?

The origins of HSS go back to ancient times, with applications, such as steel Damascus and Japanese layered swords (smelted from iron ores containing beneficial trace elements such as tungsten [W] and chromium [Cr]) that mimic current HSS compositions. Modern development of HSS in the industrialized countries began in the latter 1800s. The machine shop performance was such a quantum leap above hardened carbon steel tools, that this new tool material (better able to retain hardness at high temperatures) earned the designation *high-speed* steel. Use of proper cutting fluid flows, to cool and lubricate the cutting zone, resulted in even higher machining speeds.

A precursor to HSS, known as Mushet steel, invented in England in 1868, had this composition, by mass: 2% C (carbon), 2.5% Mn (manganese), 7% W (tungsten) and the balance Fe (iron). This was an air-hardening tool steel that later saw substitution of Cr for Mn. The first formal designation of HSS occurred in 1910 (AISI grade T1), which was patented by Crucible Steel in Pennsylvania. This alloy was quite rich in W (18% of mass), but shortages of strategic metals in WW II spawned development of HSS that substituted Mo (molybdenum) for W (grade M2). Performance was similar. The tungsten (W) HSS grades start with a T and moly (Mo) grades always begin with an M. HSS with a combined content of 10% W and/or Mo, plus proper high-temperature heat treatment are key to the legendary HSS toughness and cutting performance at elevated temperatures. The M2 composition is 0.95% C, 4% Cr, 5% Mo, 6% W, 2% V, balance Fe. Later grades, such as M42, have more Mo and much less W, plus added Co.

Exhibit 2 depicts a typical HSS twist drill bit.

Picture Credit: http://www.kalfixings.com/js/plugins/imagemanager/files/products/drill_bits/Borgh_HSS_drill_bit.jpg

HSS is loaded with finely distributed small particles of carbide (a hard ceramic phase), including carbides of Cr (chromium), W, etc. The heat-treated finished HSS tool blanks are so hard and difficult to machine that grinding is often used for final shaping (secondary operations). Besides many common industrial machining applications, HSS has found another market in upscale hand tools, such as planning blades, knives, swords, chisels, files, and handheld wood turning tools. Although not at the elevated performance level of cemented tungsten carbide (WC + Co (cobalt) or Ni (nickel) tools, HSS has a secure place in the tooling marketplace, due to reasonable cost and wide availability.

Details: Larry Rinek, Senior Technology Consultant, Technical Insights, Frost & Sullivan, 331 E. Evelyn Avenue, suite 100, Mountain View, CA 94041, USA. Phone: 650-475-4521. E-mail: lrinek@frost.com. URL: www.ti.frost.com

4. PATENT ANALYSIS OF FLEXIBLE MANUFACTURING SYSTEMS

The term flexible manufacturing system (FMS) refers to an automated machine cell, which consists of a group of computer numerical control machine tools and supporting workstations interconnected by an automated material handling and storage system with everything controlled by a distributed computer system. Flexible manufacturing systems are capable of handling different part styles with quick tooling and instruction changeovers. In addition, with he flexible manufacturing system, production quantity can be adjusted to meet the changing demands.

The flexible manufacturing system can be divided into different types, depending on the type of operation, the number of machines, and the level of flexibility. On the basis of the type of operation, , flexible manufacturing system can be classified depending on its processing operation and assembly operation. On the basis of number of machines in the system, the types are single machine cell (SMC), flexible manufacturing cell (FMC), and flexible manufacturing system (FMS). The flexible manufacturing system can also be classified based on the level of flexibility associated with the system as Dedicated FMS and Random Order FMS.

The flexible manufacturing system has various advantages. It has short setup times and queue times, offers greater labor productivity, provides greater efficiency and quality. From the patents that have been depicted in Exhibit 1, it can be seen that research is being carried out to enable the use of flexible manufacturing systems in various areas, for example, manufacturing tires, producing and packing consumer products into different packages and manufacturing products such as biologicals, pharmaceuticals, and chemicals. Some of the key patent holders in FMS include Procter and Gamble Company; Ford Motor Company; Goodyear Tire & Rubber Company; Xoma Technology Ltd.; Wes-Tech Automation Solutions LLC; BAE Systems plc; Jtekt Corporation; Hayes Lemmerz International Inc.; and Lemelson Medical, Education And Research Foundation Lp.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Flexible manufacturing system	Nov 19, 2013 / US8584349 B2	Xoma Technology Ltd.	Patrick J. Scannon, Frank A. Bernard, Alfred C. Dadson, JR., Robert S. Tenerowicz	A flexible, multi-product, multi-technology, expandable facility for manufacturing products, such as biologicals, pharmaceuticals, or chemicals, and manufacturing processes using elements of such a facility.
Flexible manufacturing systems and methods	Feb 24, 2011 / WO2011022289 A1	The Procter & Gamble Company	Patrick John Healey, James Jay Benner	A converting line comprises a first unit at a first region of the converting line and a second unit at a second region of the converting line. The first unit is positioned in series with the second unit. The converting line further comprises a third unit at a third region of the converting line and a fourth unit at a fourth region of the converting line. The first, second, third, and fourth units are configured to each perform at least one function. The third unit is positioned in parallel with the first unit, the second unit, or the fourth unit. The converting line further comprises a controller configured to activate at least one of the units based a received product order. The converting line is configured to produce a first product different from a second product during a single run of the converting line.
Flexible manufacturing system for consumer packaged products	Aug 9, 2005 / US6925784 B2	The Procter & Gamble Company	Francisco Javier Escobar, Edward Daniel Theiss, III, Christopher Robert Lyman	A flexible manufacturing system for producing and packaging consumer products into different packages is disclosed. The system includes one or more supplying means for providing the consumer products, and a multiplicity of packaging means for packaging the consumer products into different packages. The system further includes one or more conveying means for conveying the consumer products from the supplying means to the packaging means. The conveying means forms a continuous path linking the supplying means with the packaging means. The continuous path includes a multiplicity of receptors capable of accepting, carrying, and discharging the consumer products. Further, the system includes one or more stacking means for arranging the consumer products into separate stacks of products prior to packaging.
Flexible manufacturing system having modular work stations	Feb 17, 2009 / US7490710 B1	Wes-Tech Automation Solutions, Llc	Robert Weskamp, Eric Walter Nordstrom, Jason Arends	A flexible manufacturing system utilizing modular work stations configured to provide asynchronous operations on a plurality of work pieces mounted on fixtures or pallets that are transported through the system by means of a conveyor or rail arrangement. The pallets are diverted from the track on which they are transported linearly to a desired machining module adjacent to, but removed from, the track, such that the machining is performed in a chamber isolated from the track. Each machining module may be utilized in more than one location on the track and the modules may be interchanged depending on the desired operation sequence and the tools available in each of the machining station modules.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Tooling plate for a flexible manufacturing system	Jul 19, 2005 / US6918577 B2	Ford Motor Company	Abid Ghuman, John E. Robertson, Bruce Giezentanner	A tooling plate to fixture a workpiece for a vehicle subassembly is provided, including a planar body **10** for supporting fixture tools **32, 34** for holding a workpiece, a connector mechanism to allow the planar body **10** to be removably connected with a workpiece presenter **50**, and a locater mechanism **70, 72, 74** to locate the planar body **10** with respect to the workpiece presenter **50** in a repeatable manner.
Flexible manufacturing systems and methods	Mar 23, 2004 / US6708385 B1	Lemelson Medical, Education And Research Foundation, Lp	Jerome H. Lemelson	A machine tool method employs a plurality of tools which may be sequentially or simultaneously automatically controlled to perform preprogrammed operations by either the same or different work pieces. A unit of work is conveyed to be operated on by selected of the plurality of tools that are controllably operated at respective work locating positions. A plurality of command control message signals are generated to perform preprogrammed operations either in sequence or simultaneously on the same work piece or simultaneously on separate work pieces spaced apart on a common conveyor such as a flight conveyor while the conveyor is either in motion or stationary. In another form, the conveyor is automatically stopped with units of work thereon, each disposed so as to be predeterminately located with respect to a respective machine tool which has been prepositioned adjacent the work-holding conveyor. In yet another form, at least certain of the machine tools are movable parallel to the work-holding conveyor so that they may be predeterminately moved prior to and/or during operations on work. In yet another form, means are provided for transferring units of work from the work-holding conveyor to temporary platforms adjacent certain of the respective machine tools so that each tool may perform automatic operations on work while the work-holding conveyor remains operating.
Floor support system and flexible manufacturing system including same	Aug 20, 2003 / EP1097495 B1	BAE SYSTEMS plc	Jonathan Dobson, David Gillett, Ian David Mcmanus	A flexible assembly cell is made up by providing a regular array of fixed, load supporting pedestals on a concrete sub-floor on a metre matrix throughout the assembly area. Jigs and other assembly equipment required in the area are provided with base fixtures on the same meter matrix and the base fixtures are coupled to the relevant pedestals. The gaps between the pedestals are bridged by rectangular load bearing floor panels to provide a raised floor and to provide an underfloor void for routing of services. Moving a jig would be simply achieved by unplugging the relevant services, relocating the jig to a vacant set of pedestals and reconnecting the services, minimising downtime and recurring costs.

Title	Publication Date/Publication Number	Assignee	Inventor	Abstract
Flexible manufacturing system and control method therefor	Nov 6, 2012 / US8306647 B2	Jtekt Corporation	Kozo NIIMI, Koji Kito, Kazuhiro Tsujimura	In a flexible manufacturing system, a control apparatus for a transfer device stores in a memory section thereof correlation information for correlating workpieces (ante-machining workpieces) to be attached to pallets with blank materials contained in blank material baskets. When a selected one of the pallets is to be transferred to a pallet loading station, the control apparatus determines blank materials corresponding to the workpieces to be attached to the selected one of the pallets based on the correlation information and then, controls the transfer device to transfer a blank material basket containing the determined blank materials from a basket rack to a basket loading station located adjacent to the pallet loading station in connection with transferring the selected one of the pallets to the pallet loading station. Thus, when the selected one of the pallets is transferred to the pallet loading station, it becomes possible to reduce the time taken for the worker to search for the blank material basket.
Flexible manufacturing and work piece transfer system	Jun 8, 2004 / US 6745454 B1	Hayes Lemmerz International, Inc.	Jeffrey Boyd Grimshaw, Aaron Thomas Russick, Daniel D. Minor, Tom Duane Rabe, John Richard Snyder, Larry Richard Erdman, Steven Mark Sunday, Tracy William Erickson, Steven Ronald Erdman, Gary David Mason,	A flexible manufacturing line and manufacturing process employs an overhead gantry system to transfer fixtured workpieces between machining stations served by the gantry system. The machining stations include CNC machines, turret cells, and/or dedicated machines which receive the fixtured workpieces through top-entry openings. The invention provides flexibility and adaptability to variation, improved maintenance of reference position on the fixture during manufacture, improved accessibility to machining stations during operation, and increased safety.
Method for manufacturing tires on a flexible manufacturing system	Oct 5, 2006 / US20060219348 A1	The Goodyear Tire & Rubber Company	Jean-Claude Girard, Andres Delgado, Ernest Rodia	A method of simultaneously producing production runs of tires **200** on a multi-station sequential tire manufacturing system **10,** the tires **200** being from a group of tire types of different build specifications in lot sizes of one or more tires is disclosed. The steps include: scheduling the production run by imputing tire build software, wherein the software program performs the steps of: selecting the tire building equipment and materials required for the respective tire types; calculating the corresponding number of cycles each piece of building equipment must perform to build a given lot; and automatically changing to a second build specification at a lot change by switching to the second build specification after the last tire **200** of the first build specification passes; repeating the automated changing to the next build specification at each station **11-16** and **71-74**) as each last tire **200** of each prior lot passes until a final lot is produced. The multi-station sequential tire manufacturing system **10** has at least four stations for carcass **4** building, each station (**11-16**) being spaced at a predetermined distance and preferably a multistation tread belt assembly line **30** having workstations (**71-74**) separate from the carcass building line **20** wherein the carcass **4** and the tread belt assemblies **3** are joined in a segmented self-locking mold **50.**

Exhibit 3 depicts patents related to flexible manufacturing systems.

Picture Credit: Frost & Sullivan

Back to TOC