

Robotic anthropomorphic arms form the basis for cooperative robotic systems CREDIT: SERGIO DULIO



COOPERATIVE ROBOTICS

SERGIO DULIO

The pressures facing footwear manufacturers have never been greater. The demand for greater customer choice and faster delivery times, combined with the downward pressure on prices, is relentless. Particularly hard hit have been the old shoemaking countries of Europe and North America. While there have been some remarkable technical developments, one area that might have offered some relief in terms of savings on manufacturing costs—robotics—has not advanced as dramatically as many had hoped. While many other industries such as automotive manufacturing make heavy use of robotic systems, the problems peculiar to the footwear industry, coupled with the high capital investment involved, has meant that, with the exception of direct injection soling, the use of

robots is a rarity.

Sergio Dulio is well known throughout the industry as an original and progressive thinker. He was a driving force behind the EUROShoE project a few years back and since then has been developing some exciting new theories on how robotics can be integrated with human operators to create a compact and highly efficient production system; it could make a big difference for many companies within the industry. *World Footwear* considers this to be such an important topic that it has devoted a special feature in this issue to the subject based on the paper he presented to the UITIC Congress in October. It deserves to be given as wide an airing as possible and should provide much food for thought for shoemakers everywhere.

Shoe manufacturing has always been labour intensive with many operations calling for a high level of skill and experience. Conveyor systems for stitching and making departments were conceived and designed merely to transport parts from one operator to another; they did not remove the skill aspect. The introduction of numerical controlled (NC) automated shoe making machines on the one hand and robotised production lines on the other, has altered things to some degree and certainly improved efficiency. However, robots and shoe-specific automated machines stand as alternative solutions to employing human operators; they do not at present 'cooperate' in the most effective and natural way.

What is the answer? The latest concept is for robot cooperative production cells in which skilled workers perform a few valuable and high added value operations, while robots replace them in all other manipulation tasks. They incorporate the best machines available and exploit their fullest potential in terms of automation and flexibility. Compact layout, reduced floor occupation, modularity, low labour impact and easy reconfiguration are all part of a system designed to produce the highest quality products at the lowest cost per unit.

In essence, the organisation of a typical shoe factory has in fact changed very little in the past one hundred years. Complex processes are split into a number of elementary tasks in the classic Henry Ford chain approach with work in progress moving sequentially between the various machines and operators involved. Many of the overall problems are also much the same.

- Shoemaking remains labour intensive in almost all departments no matter how numerous, modern and automated the factory's machinery might be.
- Even though many machines are now capable of automatic NC controlled operations, operators remain present to supervise and control their functions and, more crucially, feed them the parts to be processed.
- Despite attempts to overcome the limitations and rigidity of mechanical conveyors, they remain a dominant feature of almost all factories. While computer controlled systems have been highly successful in adapting conveyors to sort, handle and store work in progress in stitching departments, they have yet to achieve the same degree of sophistication for lasting and making.
- Compartmentalised systems in which a production unit (say stitching) receives materials/components from an input store and sends completed uppers to an output store. Although these stores provide buffers and compensation mechanisms in the overall production flow, their place in a modern working environment is questionable.

This is the 'post-modern' scenario in which robots made an appearance in shoe factories more than a decade ago. What have they actually achieved since then?

A PRUDENT PRESENCE

Robots first appeared more than thirty years ago. Originally created to mimic and replicate the typical behaviour of a human arm, their close resemblance to the human body has resulted in them being referred to as 'anthropomorphic' robots. It took time for their cost to fall to a level where shoe factories could afford to employ them and it was in fact only around fifteen years ago that the first ones were seen. Since then, they have progressed to perform a variety of tasks in the shoemaking process.

They were first used for injection moulding applications and, in particular, the production of footwear with direct injection soling. This type of construction is characterised by a very lean production process in which the making operations (especially in the case of Strobel stitched uppers) are limited basically to the outsole injection process itself. Certain ancillary operations both before and after the injection cycle are perfectly suited to be performed by robots such that the whole making process can be virtually unattended except for the presence of supervisors. The most common of these are upper roughing, flash trimming, de-lasting and spraying mould release.

One or more robots added to the big injection carousels that make up the core of the process were able to replace human operators in repetitive yet delicate tasks requiring high degrees of throughput, attention and consistent quality which are difficult to maintain over prolonged time periods even with the best-trained operators. The cost involved when compared to the capital investment necessary for a complete carousel, including moulds and ancillary equipment, was also minimal even when robots were so much more expensive than today. Their use therefore made total sense when viewed from any angle.

These two factors combined in such a way that it is now difficult to find a manufacturing line for direct injected footwear or for moulding outsoles that does not include one or more robots to perform the tasks listed above. Over time, the robotic content of this type of manufacturing system has grown to remarkable levels, with examples in which robots



Shop floor view of the earlier EUROShoE project in Vigevano

CREDIT: SERGIO DULIO

have become less and less ancillary to the injection carousel and, increasingly, the most important part of the system with a corresponding share of the total investment.

If, on the other hand, we consider the more traditional stuck-on type of construction, the picture is rather different. In these factories, which still account for the majority of global footwear output, the penetration of robots has been much slower. Cost has certainly played a major part but, even though prices for robots now often compare favourably with that of the current generation of programmable shoe machines, they have still not gained much ground for entirely different reasons.

To perform their tasks accurately and reliably, certain preconditions must be satisfied. The lasts on to which uppers are pulled must be extremely accurate, be equipped with carefully designed positioning fixtures and, last but not least, must be firmly held in a precise position while the robot performs its task. While all these requirements are present in the more precise technology used in direct moulding, the standards required for most other types of footwear are less stringent. Last construction is cheaper and often incompatible with the presence of specific fixtures on the lasts themselves. The existing types of conveyor line that carry the lasted uppers also run in a random and unpredictable way that makes it very difficult for robots to operate properly.

It is therefore not surprising that, in the majority of factories producing this type of shoe, robots are a very careful or discreet presence if they exist at all. There have of course been examples of robots being used for applications such as roughing and cementing of the bottom and sides of the lasted upper as well as for finishing operations. This was shown to be feasible by the EUROSHE research project undertaken a few years ago. A key factor in this failure to adopt robotics is undoubtedly the availability of a large variety of dedicated NC controlled shoe machines and this, in turn, has resulted in a fresh technological dilemma.

Any of the last generation of NC controlled roughing or cementing machines performs like a robot or, put another way, a robot does its job in exactly the same way. Both perform a pre-programmed task by driving a tool, referred to as the end effector, over the shoe following a given trajectory in space. Whether the tool is designed for roughing or as a spray gun for adhesive makes no difference as either task is much the same. In fact, in this instance, there is no reason why we should not call such dedicated NC machines, robots. They are also far more tolerant of traditional shoemaking tolerances which makes them compatible with any already existing manufacturing environment and last plant.

To summarise, dedicated machines are compatible with existing conditions and have higher output. They do however require an operator to load, unload and supervise. They also have limited versatility and must be specifically programmed for each task. Robots, on the other hand, can both perform a specific task and/or simply manipulate the shoe. Their versatility is limited only by the effectors available and they are totally interchangeable.

They do however need specific effectors costing as much as the robot itself, plus more advanced programming skills on the part of operators. It is also virtually impossible to integrate them with traditional conveyor systems, so that they require a different transportation system.

OPTIONS FOR ROBOT-BASED MANUFACTURING

The greatest potential for robotic manufacturing lies in footwear featuring the stuck-on construction that is typically produced in western countries and where higher levels of automation can help to overcome some of the problems of competitiveness these companies face. There are three basic ways in which a robot might be used.

1 – Manipulating the end effector. In this first option, a specific end effector for the task to be executed—possibly arranged in a multi-tool setup where two are mounted on the same end effector—is fixed to the wrist of the robot. The shoe is mounted on a specific support (typically the pallet that transports it when the robot is part of a completely automated system) and is held firmly in place while the robot performs its task. This is a straightforward option that allows a high level of control on the spatial location of the part to be processed and, therefore, the trajectory the effector follows on the shoe.

2 – Manipulating the shoe. In this instance, a special clamping mechanism is mounted on the wrist of the robot. This is used to seize the shoe (or preferably the last via its metal interface plate) from a predetermined position and move it to one or more active stations, each performing a specific task or part of a task. In this case too the robot must follow a pre-defined trajectory (one for each specific task or sub task to be done) programmed in a similar way to Option 1. The advantage here is that similar operations such as pre-roughing, roughing and cementing, can be grouped in a single 'cell' and performed in sequence with just one robot, depending of course on the total throughput the cell is meant to achieve. End effectors in this case are placed in a precise predefined spatial arrangement. The critical factor is how rigidly and precisely the clamp is able to hold the last without causing inaccuracies in the execution of the tool path.

3 – Pick and place operations only. This is possibly the most innovative option whereby the robot does not execute any 'active' task on the shoe but merely passes the shoe to be processed from one work station to another. It is probably the most anthropomorphic way in which a robot can be used in that the task it performs is very similar to what an operator does when taking a shoe from a conveyor and placing it into an automatic machine which becomes, in this instance, the 'process automaton' equipped with its own end effector that follows a specific trajectory on the shoe in order to perform a given task or to pass it to another machine.

These are classic pick and place missions which are perfect for robots and take full advantage of their speed and dexterity. Conveyor to machine, machine to machine or, even, man to machine, are obvious possibilities. In addition,

this option has two further appealing features.

Since no active tasks are performed by the robot, no high forces are brought to bear on the shoe other than end effector contact which only has to carry the weight of the lasted shoe. Smaller, lighter and consequently less expensive robots can therefore be used. In addition, as the robot does not need to follow a precise path on the shoe, accuracy in the spatial position of the shoe and the last's interface plate is less stringent, thus eliminating many of the delicate problems previously mentioned.

While there are no examples of robots being used in this way in shoe factories at present, this idea has real potential for the future as part of a new concept for a robotic shoemaking cell. To do this, we must first consider how they actually fit into typical robot-based manufacturing lines and, then, how the robot can be made to perform all its possible applications and how shoes will need to be transported from one station to another in the production line. The way in which these two elements best interact will determine the most effective final solution.

ROBOT CELLS WITH CONVEYOR LINES

The key element of this hybrid solution is the typical conveyor that transports lasts, semi-finished shoes and components in a ring arrangement. Machines and work stations are distributed along the ring depending on the specific manufacturing sequence required and the target throughput of the line. Typical outputs range from 900 to 1200 pairs per day with 17 -19 operations and eight to 13 operators (*Figure 1*).

Robot cells are easy to integrate as they simply replace one or more operators. However, any robot cell performing a specific task is not actually served by the conveyor as the transfer of shoes back and forth between it and the cell is normally done by an operator creating, in effect, two separate mechanical components connected by a manual task. This example shows a very modern layout with predominantly automated machines and a conveyor adapted to include a dryer and a chiller. Station (9) is a robotic roughing cell that

replaces the operators normally assigned to this task. Options 1 and 2 are both compatible with this layout.

FULLY AUTOMATED ROBOTIC LINES

One can of course opt for a completely 'robot centric' approach but such a solution brings its own set of problems when producing non-injected footwear. The number of robots needed may equal or even exceed that of the dedicated shoe machines (NC controlled or manual) employed in order to cover the wide number of making operations involved and for some initial finishing operations. A pallet-based conveyor system will also have to be used. This in turn must be specifically designed to serve all the various robotic stations and also incorporate some of the thermal conditioning units (heat setter and chiller), as well as a number of specially designed machines and fixtures that complete the manufacturing sequence with operations not performed by robots or dedicated machines.

The complete manufacturing process including pallet movements, monitoring the process cycle, tracking individual lots in the line and managing the various automatic machines, is fully computer-driven to provide a high level of control on the process itself and optimal use of the robots distributed along the line. Although a relatively high number of operators will still remain, they are primarily dedicated to the most delicate and demanding 'added value' tasks or ancillary operations needed to maintain the line at its optimum throughput rate. There are already a few examples of varying degrees of complexity in operation and not producing only relatively simple, low cost footwear. The new Louis Vuitton factory in the north east of Italy, for example, uses a line of this type to produce top quality sneakers.

None of these systems are however entirely free from problems and technical bottlenecks. They are also unable to handle shoes with significantly different manufacturing cycles at the same time. It was for this reason that alternative ideas were studied in the past and prototypes built as in the case of the EUROShoE project. While they worked, none of them ever reached the market.

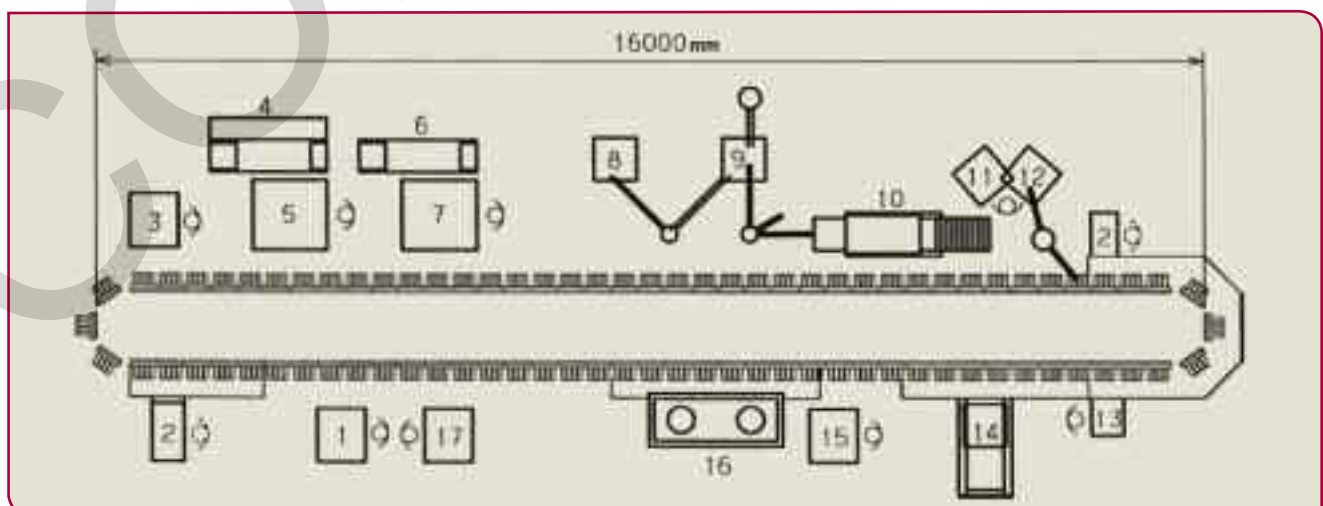


Fig 1 – A hybrid system with a robot cell (9) and a conveyor.

“...as a matter of fact...”

BUILDING BLOCKS OF A MANUFACTURING SYSTEM

Process automation must be designed and implemented following two axes, each coordinated with the other: physical operations and information management. Robots, AGV, conveyors, and warehouse systems are typical building blocks for physical operations such as assembly, transportation and storage of raw materials, components and finished products. SCADA, PLC, RFID and WSN perform the same function with information management at various levels.

Central system monitoring – a computer system monitoring and controlling a process is usually called SCADA (supervisory control and data acquisition). A typical footwear production

application would be the monitoring of equipment status and the downloading of setup parameters.

Process execution – most control actions are performed automatically by RTUs (remote terminal units) or PLCs (programmable logic controllers). They are typically used for the automation of production equipment and the management of handling and warehouse systems.

Individual identification – RFID (radio-frequency identification) and WSN (wireless sensor networks) are able to identify, position and process variables such as the temperature or pressure of each individual tagged item. Typical applications would be tagging items such as lasts, raw materials and components.

CONVEYOR LINES WITH ROBOTS AS MANIPULATORS

This final solution, still in the development stage, takes full advantage of the ability of a robot to work as a fast and flexible pick and place device. Think for example of the most modern kind of conveyor systems which incorporate all the most important thermal units, around which a full range of high-tech machines are positioned. If we exclude a limited number of operations which, no matter what the technical level of the machines used still need an active operator, any remaining human activity is likely to be merely loading and unloading machines. This is just the kind of pick and place mission a robot is well able to perform.

The next step is to have a system in which robots pick a shoe from its conveyor tray, place it in the appropriate automatic machine and then return it to the tray. This would allow us to reduce the number of operators by eliminating them from all non-added value tasks. It is, however, a rather theoretical scenario for a number of reasons.

Firstly, taking a shoe laying in an undefined and random way off a moving conveyor is not easy unless the robot is equipped with sensors such as a vision system. Secondly, automatic machines as we know them today are not as automatic as we might think; they still assume an operator is there to start and stop them, to monitor and, if necessary, correct their work if anything goes wrong. In a nutshell, they are not yet designed to operate unattended. It would require further development to make them really capable of working on their own.

It is therefore not surprising that there are no current examples of this way of using robots in shoe manufacturing. Nevertheless, it is my view that this solution is very appealing. It would offer a relatively easy upgrade of an

existing manufacturing line, with limited investment due to the decreasing cost of modern robots and potentially high savings in the long term.

HUMAN – ROBOTIC COOPERATIVE CELLS

Operators working as teams and using machines grouped in production cells have been around for quite a while. They express perfectly the lean manufacturing concept which emphasises, among other things, the value of employees and their abilities and skills. This is a valuable starting point from which to revitalise and exploit the advantages of robots.

Figure 2 shows a typical layout for the production of standard men's shoes with lasted uppers and cemented outsoles. It involves 13 active operations, 16 machines and other pieces of equipment, and seven operators for an expected daily output of approximately 800 pairs in an eight hour shift. This represents 14 pairs per operator per hour, which is an interesting figure even compared with the target figures of the most modern and efficient conveyor lines which average 14 to 18.

There are a number of advantages related to this kind of team working cell:

- Operators more efficiently employed thanks to more versatile assignments
- Defects more easily spotted and corrected due to improved employee commitment
- Work in progress lower due to the compact layout and positioning of machines
- Process time per pair lower due to fewer errors and anticipation of bottlenecks
- Non-added value operations can be minimised with a positive impact on costs

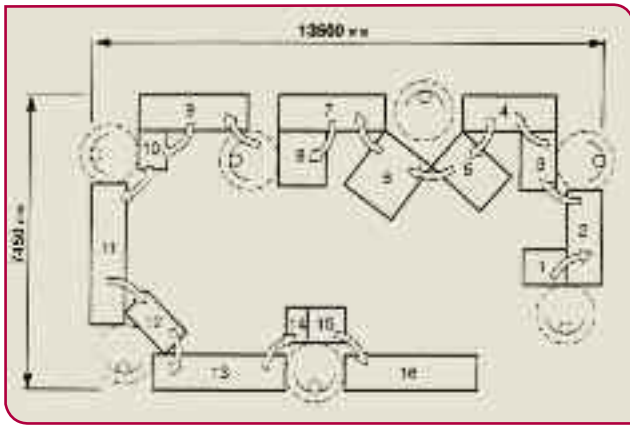


Fig 2 – Manufacturing cell for producing men's shoes.

1. Insole attaching
2. Conveyor belt (buffer)
3. Backpart moulding
4. Whole upper humidifier
5. Programmable forepart laster
6. Programmable seat and side laster
7. Heat setter
8. NC controlled rougher
9. Conveyor belt (buffer)
10. NC controlled cementer
11. Dryer and cement activator
12. Sole press
13. Chiller
14. Delasting
15. Heel nailing
16. Conveyor to finishing

Even factors such as the compact layout, reduced process time and lower work in progress requiring fewer lasts deserve careful attention. If we add other considerations such as greater operator satisfaction and motivation, we have a solid foundation for a renewed approach to the use of robots in shoe making.

Naturally, nothing is ever quite as straightforward as we might wish. For a cell system to reach and maintain its optimal performance, the quality of components entering it must be consistent, machines functioning perfectly and carefully programmed, and operators highly trained and skilled in at least some tasks. Deviations from these optimal conditions would disturb the working rhythm of the cell and severely impact productivity. Viewed from another perspective, adopting this type of manufacturing calls for discipline, rigorous manufacturing standards and the use of 'best of breed' machines, which would in turn be highly beneficial for the factory overall.

Now let's see how robots can fit into this picture. The seven operators in the cell perform the following tasks:

- a. Attaching the insole to the last and placing it on the first conveyor
- b. Inserting and moulding the counter and placing the last and upper on the next belt
- c. Toe, seat and side lasting using two machines
- d. Loading and unloading the bottom roughing machine
- e. Loading and unloading the bottom cementing machine
- f. Outsole attaching and pressing
- g. Delasting and heel nailing

If we analyse these tasks in terms of added value, we see there are two where a high level of skill and attention is required because their correct execution greatly contributes to the quality of the finished shoe. These are operations (c) and (f) on the list. Three other operations, (a), (b) and (g) use relatively simple machines, while (b) could even be taken off the cell with a different arrangement of the components such as having uppers delivered with counters already inserted and moulded. The two remaining operations (d) and (e), have no added value at all. This cell therefore has the potential for a further reduction of two or more operators

If we revise this layout slightly, there is an opening for a new use of robots. The layout in Figure 3 has been arranged with sub-cells containing groups of homogeneous operations.

The sub-cells at the beginning and the end of the making sequence have one operator each (although a third operator in this area would be advisable for smoother and safer functioning of the entire cell) while the other two each have one robot. Exchange stations are placed at the nodal points of the cell to allow the transfer of semi-finished shoes from operator to robot or from robot to robot. The main characteristics of this very clean and compact layout are clear:

- No conveyors or other kinds of transportation systems
- Close cooperation of human operators and robots
- Built-in buffering capabilities

A closer look at the operations performed in the different sub-cells shows that in the first (Figure 4), one operator performs toe lasting and other preliminary operations. In the robotic second one, the lasting of the upper is completed and the bottom of the shoe is, after the required heat setting stage, prepared for cementing. The next sub-cell (again fully robotic) completes preparation of the shoe bottom up to the application, drying and reactivation of the cement. Finally, in the last sub-cell, the second operator completes the attaching of the sole and heel to the lasted shoe, delasts it and forwards it to the finishing line.

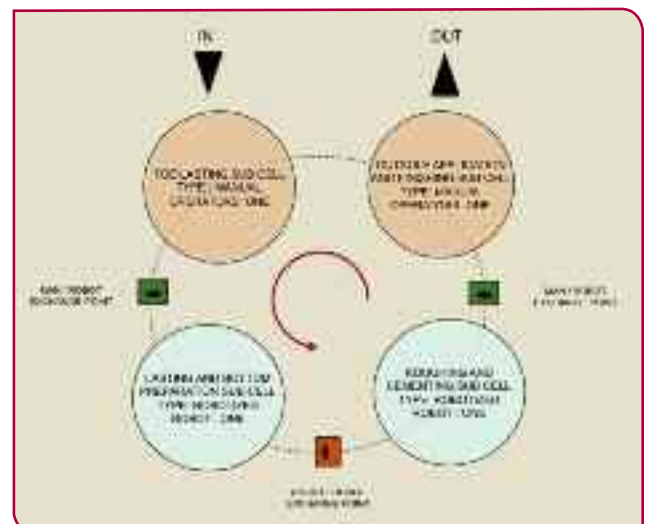


Fig 3 – Revised layout containing four sub-cells.

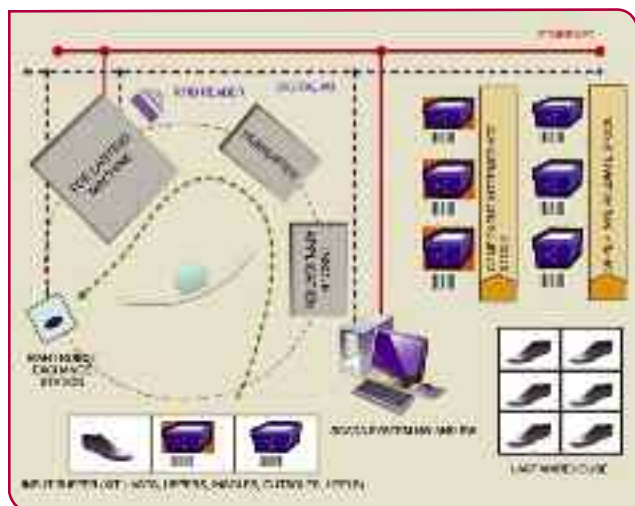


Fig 4 – Details of the first sub-cell.

The first sub-cell of the system includes the following machines and work posts:

- A simple insole attaching machine
- A whole upper humidifier
- A programmable state of the art toe lasting machine

One or two operators attend this sub-cell and they perform the typical operations leading up to the key step of toe lasting. Insole attaching is a relatively simple and quick task that is compatible with the processing times expected from the cell. A key element of the system makes its appearance at this point in the form of a double communication channel. Digital signals are used for the synchronisation and message exchange protocol. These are handled by a low level communication bus (typically a field bus) and supervised by a cell controller which supervises and manages the entire cell at all levels. A second, high width band communication channel (Ethernet), is used to convey tool paths to each relevant machine.

Another important feature is the identification and tracking system, where it is thought a range of RFID tag readers would be fitted to every machine in the cell so that they could execute a predefined program for each single shoe to be produced, either independently or with operator assistance. The machines are now capable of identifying the shoe loaded and of retrieving the appropriate program by themselves.

A second important function of this system is the tracking of all items present in the cell, such as for example a last carrying a shoe at various stages of the making process. This is a good starting point and allows precise tracking of where each lot or part of a lot is in the manufacturing sequence. It does not however exploit the full potential of digital identification and tracking. With a little more technological vision and moderate development effort, one should be able to tag virtually all components entering the cell (lasts, uppers, insoles, outsoles and heels) so as to cover not only the tracking task but also reduce, if not entirely eliminate, the risk of mistakes in combining the various elements of the assembly kit. This takes us on to the first of the two totally robotic sub-cells (Figure 5).

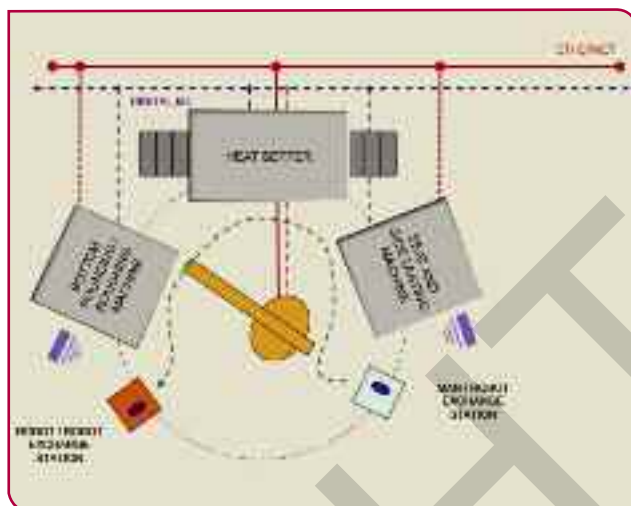


Fig 5 – The second sub-cell.

The machines installed in this cell:

- A fully programmable seat and side lasting machine
- A heat setter with conveyor
- A bottom pounding and roughing machine

The robot's sole task is to transfer shoes from machine to machine. It receives them from the first operator, transfers them to a heat setter, then to a bottom pounder/rougher and, from there, to the next robotic cell through an exchange station. This takes full advantage of a robot's ability to perform pick and place missions accurately and at high speed, particularly as it only has to carry a relatively light last and upper. The choice of a combined pounding/roughing NC machine is arbitrary and made to incorporate the highest possible level of flexibility, allowing the processing of shoes for which a pounding of the bottom after lasting is recommended as well as those where is not required.

A second feature used to full advantage is a through-conveyor heat setter as a form of natural buffer. The ability of this type of machine to accommodate a number of pairs of shoes at a time can be used to compensate for the unbalanced duration of the upstream and downstream operations. Should other buffers be needed, small transfer conveyors can be added.

The reason for locating the seat and side lasting machine in an unattended area might be questioned. Whilst there are no doubts whatsoever that toe lasting requires very skilled operators, it is at least debatable whether they are strictly needed for seat and side lasting machines. There is a school of thought that says this operation needs an operator to control the machine and make sure the lasting is completed correctly. This is possibly very true in the case of high quality ladies shoes where side lasting of the sides poses challenges for even the most modern integrated machines. On the other hand, it is equally true that in many other instances and, with extra care in creating upper patterns, the problem can and has been overcome such that an operator is no longer necessary.

The third robotic sub-cell (Figure 6) is much like the first and comprises three work stations:

- Side roughing and cementing

- Bottom cementing
- Cement drying and reactivation

Some of the machines chosen might appear unnecessary but, for this exercise, it is justified by wishing to give the cell the highest possible level of versatility by accommodating shoes with simple trimmed outsoles as well as walled ones; depending on which they are, the robot will pass the shoe to the appropriate machine as directed by the cell controller.

The transfer of semi-finished shoes from one robotic sub-cell to another occurs at an 'exchange station'. This can be either a very simple stand on which the last is placed by one robot and taken by the other or a more complex rack that can act as a buffer between the first and the second robotic cells with the storage capacity of the rack depending on the balancing requirements between the two. As a final task, the robot picks up the shoe at the exit of the drying/reactivation tunnel and passes it on to the next operator through the second man/machine exchange station.

The fourth and final sub-cell (Figure 7) features the following work stations:

- Outsole application and pressing (with pressing machine)
- Chiller
- Last pulling off
- Heel fixing

This last group of operations basically completes the shoe. As this sub-cell has an operator, the order in which the various machines appear is less critical. For instance, by changing the sequence and, if necessary, introducing other machines, two-step heel attaching (pre-fixing on the last and final nailing after delasting) can be accommodated.

This type of production system has no rigid barriers between the areas in which robots operate and those in which operators are present. The two are therefore able to cooperate in a seamless environment, with each covering tasks most suited to their nature; added value for operators and highly repetitive, non-added value for robots. Transfers between operators and robots are made through exchange stations.

The latter were in fact introduced primarily for safety

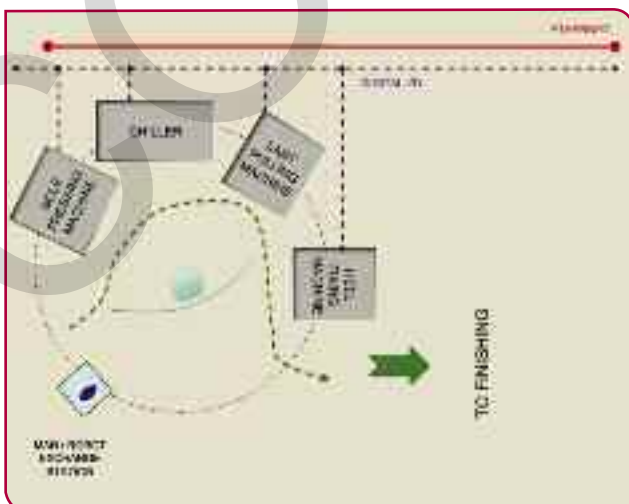


Fig 7 – The fourth and final sub-cell.

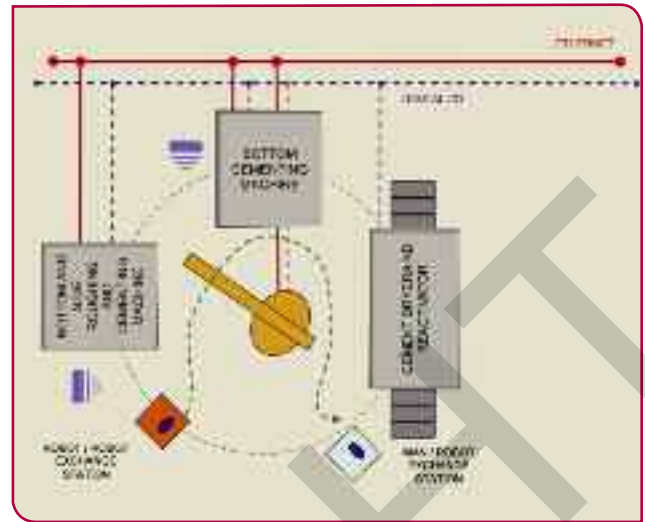


Fig 6 – The third sub-cell.

considerations as dictated by the current set of norms in terms of operator/machine interactions. It is foreseeable that, before long, direct transfer of shoes from operator to robot and vice versa may well become possible. It would eliminate this final barrier and remove any physical separation between human operators and their anthropomorphic clones to create a true 'human – robotic cooperative production system'. There are also a number of further interesting aspects stemming from this new concept.

Modularity – the whole system can be looked at in terms of modules. Each active post or machine is a module that exchanges signals and data with the cell supervision system through the assistance of either humans or robots. Robotic tasks can also be broken down to a limited number of typical exchange modules (machine to machine, machine to buffer or machine to operator) whose scope is always the same and whose spatial parameters are only dependent on the individual machine and its location within the cell.

Plug and make reconfiguration – the total absence of any kind of rigidly installed transportation system, whether conveyor or automated pallets, makes it very easy to reconfigure it depending on specific production demands. The transportation function in this case is performed by operators and robots, and the path each shoe follows is software defined rather than hardware implemented.

If we imagine the system to be completed by a set of standards defining how the last is clamped, how a machine connects to the low level bus, how programming data is exchanged and with which format, where the machine is located and the XYZ coordinates of its relevant points for the pick and place missions of the robots, we soon have a scenario in which any machine complying with these standards can be easily 'plugged' into the system to start making shoes immediately.

Reversibility – this refers to the possibility of reversing, still with the same logic structure, from an 'intelligent machine scenario' as described so far, to an 'intelligent robot' one. We have thus far assumed that the unattended process steps were performed by 'best of the breed' NC

controlled machines, with robots simply transferring shoes from one machine to another. Unfortunately, not all companies can afford a full set of these highly efficient but extremely expensive machines.

The concept still holds good, however, if we think of replacing the intelligent machines with a set of simple low cost tools with which our robots will process the shoes. We simply switch from Option 3 to Option 2 as described earlier and shift the 'intelligence' factor or capability of executing a given process step following a pre-defined tool path or trajectory, from the machine (which disappears) to the robot. Now, we achieve the exciting goal of transporting the shoe from one point of the cell to another and performing the required processing steps by just using the robot at a much lower investment cost.

A final point concerns the logistics of the making cell or,

in other terms, how each relevant component is stocked, dispatched to where it is needed and tracked through the manufacturing process. This is certainly another key aspect to be considered, because the actual success of the whole solution very much depends on how cleverly this issue is dealt with and how some critical aspects are tackled.

- Size, position and management of the last store is vital as the cell must be fed regularly with the necessary lasts and that they are ready for use when the relevant order enters production. While this is a common balancing problem in almost all manufacturing systems, it is particularly relevant here due to the very small work in progress of the line and its extreme leanness.
- Size and control of the input component store (uppers, insoles, outsoles and heels) is also important. The first issue to be considered is the correct matching of the

various elements of the assembly kits. All the components must have the correct specification to go with the last and of the right size. Any mistake here can have disastrous effects on downstream production. A clever mixture of robotics and RFID tagging can provide an elegant solution to this problem and a form of robotic component rack exists that could well provide the answer. The second is the easy delivery of the required components where they are needed in the cell; uppers and insoles first, followed by outsoles and lastly by heels. The relative compactness of the suggested layout does ease this to a certain extent, allowing the store to be located within easy reach of the required work stations.

Although there are many attractive aspects to this manufacturing concept, some legitimate questions still remain. Does it actually work? What sort of output per operator and in total can it achieve? How does it compare in terms of investment with other systems? In order to support the assumptions made so far, a simulation model of the entire making cell has been produced and a simulated trial conducted in which cell behaviour in different working conditions and with different configurations can be analysed.

The target figures that could be achieved are revealing:

- Expected throughput – approximately 340 pairs per day

**GREEN.
GREENER.
GREENEST.**

See the latest additions to our
environmentally friendly Dr-Lex Eco Collection
at the NE & NW Apparel & Footwear Material Show

DR-LEX Eco®

The Original just keeps getting better.

New fashioning fabrics with recycled, renewable & sustainable yarn.

Faytex Corp.
www.faytex.com

Tai Loo Textiles Co., Ltd.
www.katit.com

- Productivity: comparable to traditional systems at up to 14 pairs/hour/worker
- Number of operators – three
- Number of robots – two

The trial has also provided additional data on the total cycle time for each sub-cell and for the entire set up. These outputs allow a comparison to be made between the proposed concept, the revised system shown in *Figure 6* and a typical conveyor-based line with the same number of operations and operators so that a comparative economic assessment can be made.

CONCLUSIONS

In the recent history of shoe making there have been a few innovations that really changed the way things were done. Injection moulding of outsoles brought in a new way of constructing the shoe that opened new perspectives in terms of process simplification and product variety. CAD/CAM systems drove the footwear world into the digital domain and fostered the introduction of a digital culture across a traditionally conservative industry. Die-less, NC-controlled cutting took full advantage of modern electronics and computer science to provide technological answers to the changing demands shoe companies were facing for greater flexibility, versatility and quick response. Is a new revolution now around the corner?

This is difficult to answer. Automation and robots alone are not the solution to the many problems shoemakers, particularly in western countries, have to face nowadays. In recent years growing product variety combined with ever higher customer expectations and the challenge of maintaining costs within a reasonable bracket to remain competitive has made the life of shoemakers ever tougher. For the majority of footwear manufacturers struggling to defend their position in a tough global market, the added pressure of every customer wanting something different is a nightmare. There are others to whom it is an exciting opportunity.

Some may therefore have at least dreamed of a future in which shoes flow from the production line almost by themselves thanks only to very intelligent machines and

systems rather than human labour. Then again, perhaps this is also a nightmare because, to some, completely removing any “human touch” is like depriving a shoe of its soul; the truth as usual lies somewhere in the middle.

Human operators, robots and machines need to cooperate in a cleverer and more effective way than has been the case up until now. One possibility with the potential to begin to answer this conundrum lies in the advent of a new type of system to satisfy the production demands of shoe companies. Less single machines and more production systems, less specialisation in single process tasks and more comprehensive solutions to specific production needs, less rigid systems and more lean and flexible solutions, and, eventually, less hardware and more software and knowledge. This might not perhaps be a revolution in itself, but an exciting mutation of the industry as a whole. 🍷



Just Add Leather

You supply the craftsmanship, A&E will supply the high performance threads, such as Anofil Nylon® and Anofil Poly®. Introducing Anofil Nylon® DRY, our new technically advanced non-wick sewing thread, which provides exceptional quality and enhanced durability. Whether it is for footwear, sporting and recreational products or any sewn product demanding quality, A&E has the thread for you.

www.amefind.com

A&E
The World's Greatest Threads