

RAMS in action

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Until today, the application of robotics in the footwear world developed along two lines. In the first, robots act as operating machines and are therefore equipped with end effectors specially designed to perform a given operation such as roughing or cementing, that execute their task with the last held in a fixed position. In the second, robots work as manipulators which handle the last and perform the task by bringing it into contact with a given tool such as a roughing head that is held in a fixed position.

These solutions are less than optimal as they imply the use of palletised or otherwise modified lasts to allow the robot to process them precisely. This normally means that shoe companies are obliged to replace part or all of their lasts with new ones suitable for the automation process. This very often turns out to be a relevant obstacle for the introduction of automation in the company. Further, they do not exploit the actual capabilities of existing NC machines designed to perform a wide range of different operations such as bottom pounding, roughing and cementing, consolidated over the years by machine manufacturers' long experience.

The RAMS system, or Robot Assisted Manufacturing System, developed by ATOM MB the Digital Manufacturing Division of ATOM Group, was conceived to overcome these limitations. We have already covered the concept in its general aspects in *World Footwear* Jan/Feb 2018 issue of and now, 18 months later, the system has reached a first level of maturity and has been deployed in production at the manufacturing site in Italy of a well-known international brand of high-end footwear. In this article we will give a full update on how the system evolved and on the manufacturing experience it has provided so far.

PHILOSOPHY BEHIND RAMS

Before diving into specific technical aspects, it is worth recalling 'philosophy' that underlies the entire development approach of the RAMS system. In order to do so, we must take a step back in the history of robotics. Isaac Asimov, the famous science fiction novelist, in his 1942 short story 'Runaround' devised for the first time a set of rules called the Three Laws of Robotics, quoted as being from the Handbook of Robotics, 56th Edition, 2058 A.D (or just less than forty years from now.) These laws form the ethical foundation for humanoid robot behaviour as far as the science fiction world is concerned.

It is interesting to see how these laws, built each one on top of the other, form a simple yet effective code of conduct for the robot to interact with its environment and specifically with the human beings it shares its world with, something that sounds very close to the application domain of so-called cobots. The first of the three laws stipulates that *'a robot may not injure a human being or, through inaction, allow a human being to come to harm'*. The second one states that *'a robot must obey the orders given it by human beings except where such orders would conflict with the first law'*. And finally, the most important one, *'a robot must protect its own existence as long as such protection does not conflict with the first law or second law'*. Similarly, the RAMS design complies with a set of specifications that we can call 'the three laws of footwear robotics'.

The first one is the adaptability law whereby a footwear robot must adjust to the manufacturing environment rather than vice versa. It must seamlessly integrate into the manufacturing process, adjusting to its peculiarities and specific demands without forcing the company to completely revolutionise its manufacturing process, unless

Overall view of RAMS.
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Two robots tending the machines.

this is for improving overall efficiency. An implementation of this law is the possibility to use standard production lasts instead of more costly special ones specifically designed for robots. This results in cost savings and a lowering of investment barriers.

The second one is about flexibility. A footwear robot must be able to use all the automatic machines when available, taking the utmost advantage from their existence to allow maximum flexibility, modularity and rapid setup for low costs and quick returns. This is another corner stone in the RAMS architecture. Robots only perform smart pick and place operations to tend NC controlled machines to which the true steps of the manufacturing process (lasting, pounding, roughing and cementing) are devoted. This, of course, calls for a very deep integration and synchronisation between each machine and its robot servant.

And finally, a last law that we may call human-centricity. Paraphrasing Asimov, this states that a footwear robot may not injure workers, must guarantee their safety, co-exist with them and valorise their capabilities. It must also fit into the manufacturing process with the highest safety standards for operators and, at the same time, without introducing elements of rigidity. In this respect

RAMS does not use any rigid fencing or other fixed protection systems but is solely based on laser barriers that sense and intercept the presence of workers in their safety areas and adjust the robot's speed (until it is completely stopped if necessary) accordingly. With this in mind, let us see how this architecture has been actually implemented in production.

MECHANICS OF RAMS

The first pilot customer of the RAMS system is a manufacturer of high-end men shoes with a classical manufacturing approach using lasted uppers and cemented outsoles. The material used for both the uppers and the soles is predominantly leather of different kinds, although synthetic materials are also present in their range. Special attention was requested in the development of the automation solution due to the fact that the company adopts a pre-finishing step where, after lasting and stabilisation in a heat setter, all uppers are creamed and polished before moving on to the bottom preparation phase. This means that the shoes must be handled with extreme care by both human workers and robots in order to avoid staining, scratching or damage of any kind during transit of the shoes in the RAMS robotic cell.

The cell itself covers four operations. The first is pre-roughing of the lasted bottom of the shoe with a coarse tool followed by roughing with a fine one. The shoe bottom is then primed with an initial pass of a highly diluted water-borne adhesive that penetrates the open fibres of the upper material and provides an adequate substrate for the following phase of actual cementing with the same kind of adhesive at a higher viscosity. Priming and cementing are separated by a very fast drying step of only a few seconds that is performed directly in the machine.

These four process steps are covered with two NC machines from the ATOM MB CD range: CD10 for pre-roughing and roughing and CD3 for priming and cementing, each one featuring a dual carriage so as to perform two operations on two shoes simultaneously. Although in principle both machines could be served by just one robot, in this specific case two of them have been used in order to reduce the duration of the picking tasks in and out of each machine to a minimum. The robots in use belong to the Mitsubishi RV family, the specific model being the RV-13 FRL Q series with a maximum payload of 13kg. A crucial part of the manipulation solution is a custom, four finger gripper, specifically designed by ATOMLab, the innovation division of the ATOM Group that was also involved in the definition of the cell architecture and in the development of its software.

The gripper can handle lasts with different designs (pointed, sneaker, ankle boots, etc.) and various sizes with no need for reprogramming or reconfiguration. This allows the cell to process a wide range of shoe models of different complexity and low or high cut uppers, with a high level of flexibility and virtually no setup time. Finally, the two machines and their respective tending robots are placed on metal platforms, designed around a modular octagonal shape that can be arranged in multiple configurations and, moreover, provide a rigid connection between the robots and the machine as well as between the two robots themselves. As a result, there is no risk that, due to their high acceleration and reduction in speed, robots and machine may lose their



RAMS cell control station.

relative positions causing problems when the shoes are loaded or even collisions with their structures.

RAMS IN OPERATION

The 'core' of the cell, comprising the two CD machines with their tending robots, is completed by other elements that are necessary to integrate it with the manufacturing steps that happen upstream and downstream. A palletised transfer line provides an input and output buffer of shoes, a pallet-to-robot transfer station and a robot-to-robot exchange buffer between the two machines. Shoes are normally transported on trolleys from the lasting area through the pre-finishing operations to the cell, each trolley carrying batches of 10 pairs of shoes with their respective outsoles.

When the trolleys arrive at the cell an operator transfers each shoe from the trolley to the first available pallet. He then processes the outsole with an automatic cementing machine and places the cemented outsole into a special compartment of the same pallet so as to guarantee the shoe and its outsole correspond. Although this operation is currently done manually, an automated solution is under study that will use a further robot to load shoes and outsoles onto the pallet.

Once on the transfer line, pallets are buffered and transported to the pallet-to-robot exchange station. Here the pallet is clamped, the shoe centred by a

dedicated mechanism and the first robot commanded to pick it and place it in the first station of the first machine (CD10). The centring and aligning mechanism is a full machine in itself and is a very important component as it insures that each shoe, no matter how big or small the last is or how low or high its upper, is perfectly loaded in the CD machines and similarly perfectly processed. When the two roughing steps are complete, the CD 10 machine informs the cell supervisory software (a special PLC program that acts as the 'brain' of the entire system) that a shoe is ready to be passed to the next phase. This commands the first robot to pick it from the machine and to place it in the robot-to-robot exchange buffer that has the function of passing the shoe from the first to the second robot.

The sequence is then repeated for the cementing machine. The second robot takes the shoe from the buffer and loads it into the first machine station (priming). At the end of the cycle, the fully cemented shoes are retrieved from the CD3 machine and placed in the destination pallet that in the meantime has moved to the deposition station, still carrying the previously cemented outsole. Eventually all pallets carrying cemented shoes and outsoles are buffered and blocked in the final stop position where a second operator transfers them to a dryer/reactivator and then finally to sole attaching and pressing.

This further manipulation operation could again be executed by another robot and a solution for this is currently under study. Cell operations are constantly monitored by an HMI/SCADA software that provides operators with an at a glance overview of the cell and other devices' status, alarms, pairs produced, OEE (overall equipment effectiveness) and other overall parameters. The supervisory station is a complex four display setup that features in one single installation the RAMS cell HMI, remote consoles for the two CD machines allowing the operators to control them remotely, even though they are a few metres away from the post, and a composite display of four close circuit video cameras showing the interior of the two machines while they work.

A PROMISING START

After a long test phase with a simplified lower throughput cell that lasted from June last year until this April, the first production line was delivered and installed later that month, switched on at the beginning of May and is currently (June 2019) completing its ramp up. After roughly a month of production and data recording, the expected target throughput of 750 pairs in a nominal 480-minutes shift has been confirmed. Recent measurements indicate an average time of 17 seconds per shoe (34 second per pair) which is equivalent to a nominal throughput of approximately 850 pairs per day, with margins to further increase this to 900 pairs.

With a typical OEE of 83% percent (all included and potentially improvable) the cell is expected to achieve its design target of 750 pairs per day with a total of two operators to serve it. A second cell with the same capacity is planned for installation in August next year which will bring the overall manufacturing capacity of the company to 1500 pairs per day and well above their current manual throughput. There is also potential, as a next implementation step, to replace manual loading and unloading operations with further robotics. All in all, it has been a very promising start for a robotic solution that is the latest to enter the footwear automation arena and one that is no more than two years old. 📌