Garden chairs: an example of synergy between injection moulding and integral skin Polyurethanes

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Abstract

During 1997 the Cannon Group incorporated the activities of Sandretto, the largest - and one of the earliest - Italian producers of injection moulding presses. Immediately after the acquisition a series of R&D projects were initiated, to look into all the possible synergies between current and newly acquired technologies.

The first project that brought practical results was the study of an injection moulded plastic part over-moulded with flexible Polyurethane. The product, a plastic garden chair with a very comfortable foamed seat, was produced at K'98 in the Sandretto stand.

This paper presents the details of the project, and the potential development deriving from the combined use of plastic's injection moulding and Polyurethane foaming.

Synergies, when one plus one can make three

One of the firsts tasks that Cannon's management decided to get involved into after having acquired the activities of the Sandretto Group in 1997 was the definition of possible areas of synergy amongst the current business and the new one. Injection moulding technologies were new to Cannon, but being already involved in Polyurethanes, compression-moulded composites, thermoforming, and industrial electronics offered a wide range of potential opportunities to investigate.

Examples of immediate synergies included - as an example - injection moulding of PVC encapsulations for automotive windows, using dedicated handling and clamping solutions used for more than ten years with Polyurethane formulations. Or synchronised injection moulding of plastic housings for automotive and domestic lighting systems, to be immediately followed by the application of a foamed gasket - made out of expanded Polyurethane - into the narrow groove designed on the housing's edge. Or the combined use of a horizontal plastics injection group with a vertical clamping press, to produce injecto-compressed parts.

Each of these possible combinations has to be analysed to verify market's needs, technical feasibility, patenting situation, and true benefits provided by the new solution proposed: if the technology holds water these are - without exception - good examples of synergy that provide new opportunities to the market.

By adding existing technologies (as when adding one to one), with some creativity added in between, they do provide easier or better ways to manufacture a product and open a new business opportunity for the supplier of the equipment. This will not cause industrial revolutions, but it's like getting three summing one to one!

The Chair project

One project particularly appealed the Group's management, attracted by its potentially wide number of end uses: the application of a layer of Polyurethane over an injection moulded part immediately after its demoulding.

The idea is apparently simple: injection mould a thermoplastic part, place it - immediately after demoulding - in a foaming station and inject a flexible integral skin formulation on it. The different mechanical and functional characteristics of the two plastics, combined, provide significant added value to the end product. Polyurethane adheres on most resins and - being injected in liquid stage - can fill holes and grooves of the plastic piece, providing a stable fixing even when the injection moulded one is made of Polyethylene or Polypropylene and no adhesion is obtained between the two parts.

The idea is not even new, since for many years various parts have been produced over-moulding an injection moulded plastic insert with a Polyurethane foam. The interesting aspect of this project is that this process has been conceived as a co-ordinated sequence of operations, for an industrial application and the production of a mass product. The sequence of operations can be automatised, cutting the cost for intermediate storage and handling; exploiting the temperature of the just-made plastic part the flowability of the PUR formulation can be improved, getting optimum fill and surface aspect while saving some of heating required by a Polyurethane foaming process. Differences in cycle time between injection moulding and foaming can be compensated using a turning table with more foaming stations, indexed near the injection moulding press.

The desire to realise one of these synergetic projects and to show it at the K'98 fair pushed the Group Management to start a project that would involve different Group Units. A candidate for this project was identified in a mass-market product, the garden chair.

A popular piece of furniture, the injection moulded chair is produced today in millions of pieces per year. Several models and shapes are available on the market, to respond to the different tastes and requirements of the countries where a good solar exposure allows for the outdoor markets and large sales volumes have progressively reduced the final prices - and the producer's margins. An idea to add some value to this popular project would be well received by various producers, who had already expressed at various occasions their interest for a more sophisticated model. *(Picture 1)*

Picture 1: A garden chair in Polypropylene

The solution proposed by Cannon was to inject a coloured Polyurethane seat - made with a flexible integral skin formulation - over a Polypropylene injection moulded armchair. Comfortable seating, appealing colour, water-proofing and resistance to outdoors weather - provided by the Polyurethane cushion - linked with the structural resistance and a fast moulding cycle - typical of Polypropylene - would match perfectly and improve the product's value, aiming the distribution to a segment of market more oriented towards comfort and style rather than to a low cost.

Various technological problems had to be solved when designing a proper industrial system for this project.

The Chair

In order to cut development time and cost it was decided to use an existing model of chair. STIL GARDEN, a major producer of plastic furniture for outdoor use based in northern-Italy, showed interest in the project and agreed to supply the necessary injection moulding tool and some dozens of chairs for the development work. Fitted with armrests, the chosen model was characterised by a number of holes in the seat and in the back, designed to help the transpiration, for styling purposes and for weight reduction. A trapezoidal seat was designed over the existing seating surface, with a light texture on the exposed surface. *(Picture 2)*

Picture 2: The integral skin PUR seat designed to fit the injection moulded chair

The injection moulding machine

The injection moulding machine and tooling did not require major modifications: a Sandretto Mega TE F with 1100 Tons of clamping force was fitted with the production mould supplied by STIL GARDEN.

In order to ensure the best conditions for mould filling and avoid air entrapments, it was planned to inject the Polyurethane foam from the lower part of the seat: the holes present in that area were an ideal pouring location, and could provide optimum venting of the mould. This required the addition of a revolving device between the injection moulding machine and the foaming press, to turn 180 degrees the chair before placing it into the foaming jig. The other modification required in this part of the plant was the extension of the demoulding robot's rail, in order to reach the foaming area, and some programming for the extra movements required.

PU foaming: tool and mouldcarrier

The design of the prototype foaming tool was made on a real chair, simplifying the job of the tool makers. An aluminum tool was foreseen, to reduce development time and cost, fitted with water circulation system for precise temperature control.

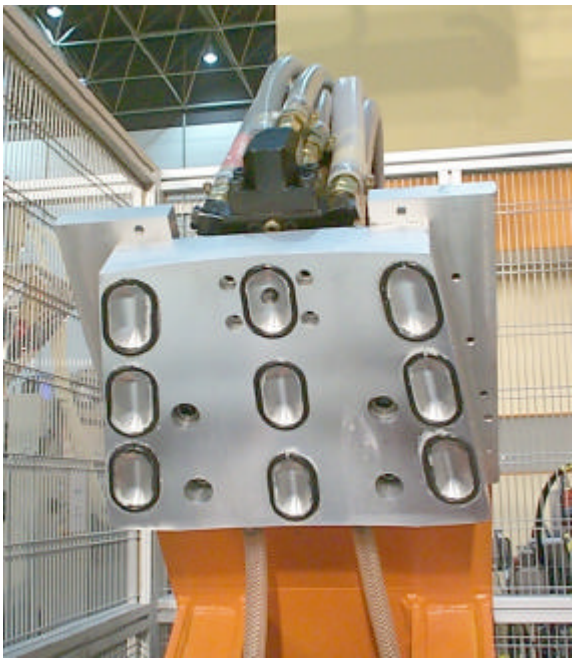
Working with a warm chair little or no heating would be required, while sometimes some cooling could be used to provide better skin effect and faster demoulding times. A decorative texture was photo-engraved on the lower mould's surface, and nine holes were made on the upper mould-half: one of them was designed to hold the nose of the mixing head. *(Picture 3)*

Sealing rings were foreseen around the nine holes to guarantee a proper tightness and avoid leaks. Adhesion between Polyurethane and Polypropylene was not requested. For recycling purposes it would be better to tear out easily the Polyurethane seat from the chair, and in case of mechanical damage to the foamed part its easy removal would permit the further use of the chair without it or with a spare seat. For this reason the nine venting holes in the upper mould-half were made: some Polyurethane was left free to escape from the holes, and - expanding in free rise out of them - provided the "mushrooms" that guarantee a firm connection between seat and plastic support even in absence of real adhesion between the two. *(Picture 4)*

Picture 4: the 9 PUR buttons that hold the seat in place

A book-opening mouldcarrier was defined, able to work in both stand-alone and carousel-mounted foaming configurations. To provide maximum flexibility and allow its use with a wide range of chair models, the dimensions of the upper platten were limited to the very minimum footprint. The mixing head was placed in the front side of the upper lid, so that foaming could be achieved with both a fixed head - for stand-alone presses - and a robot-mounted one for use on a turntable or a carousel. *(Picture 5)*

The features of this hydraulically-operated mouldcarrier included a clamping force of 100 Kn at 125 bar, adjustable from 2 to 6 bar over a mould of approximately 300 x 300 mm, 55 degrees book opening of the upper lid and 100 mm of parallel stroke for the lower platten.



Picture 3: Details of the PUR-foaming mould

PU foaming: metering unit and mixing head

No specific extra work was foreseen for the metering and mixing section of the project. A conventional Cannon "A-System 40" metering machine was used, with an FPL 14 mixing head. The standard features of this machine's series allow for an optimum dosing of a two-component flexible integral skin formulation.

For the development work Dow Italia supplied Specflex™ NR 473 polyol and Specflex™ NE 117 isocyanate, a grade producing a 300 g/l density, 48-53 Shore A hardness foam, characterized by cream time of 12-16 s, gel time of 50-60 s and 4 min demould . This foam is particularly resistant to tear and has a very good compression set.

Picture 5:the foaming press, with a ready chair

Working at medium-low output a bubble-free, very homogeneous filling of mould was obtained.

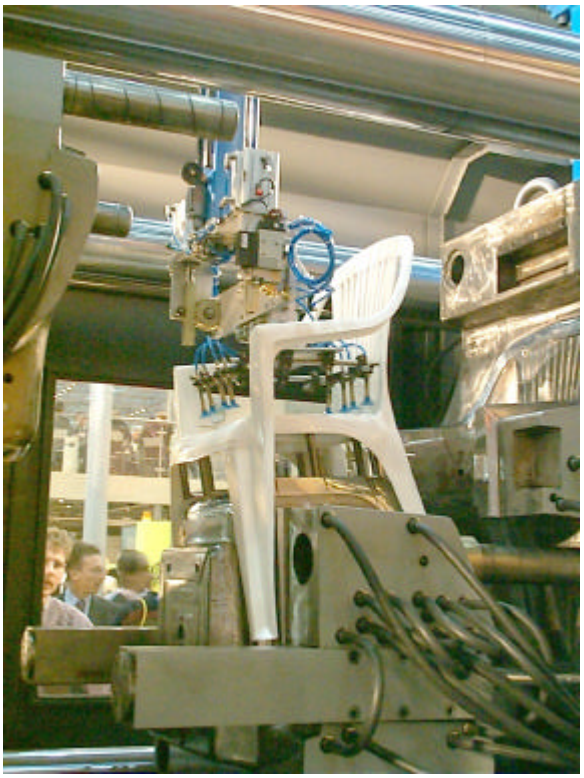
Preliminary results - problem solving

When mould, mouldcarrier and chemicals were available the foaming trials started in Cannon central R&D lab near Milano, Italy. Using the few dozens of moulded chairs supplied by STIL GARDEN a wide range of moulding conditions was tested. The possibility to program the shot weight by the machine's computer and the precise and repetitive performance of the dosing unit greatly helped in finding the right amount of foam that would fill the mould cavity and provide nine equal "mushrooms" out of the venting holes. A special Silicone lip-seal was designed for the perimeter of the seat, to avoid any flash of foam over the plastic and the related manual trimming.

When ready, the whole Polyurethane foaming station was transferred to Sandretto factory in Turin where the injection moulding machine chosen for this project was in the final stage of testing. When working in combination with the injection moulding machine some differences with the previous phase of lab development arose: the dimensional behaviour of a warm "just-moulded" chair is different from that of a re-warmed one. Shrinkage and flex modulus differ significantly, and sealing the plastic insert to avoid Polyurethane leaks - as expected - proved to be the most critical part of the system. An accurate study had been made to ensure proper clamping conditions in a range of temperatures going from that of the warmest piece (immediately after demoulding the plastic chair from the injection moulding press) to that of the coldest one (when foaming cold chairs taken from a buffer storage). Shrinkage and flexural modulus of the Polypropylene moulding at various temperatures had been simulated using FEA (Finite Elements Analysis). A special, self-adjusting clamping device had been applied over the mould to compensate the thickness difference between these two extreme conditions and ensure proper sealing.

In spite of all this, still some leak of foam was present in the warmest foaming conditions, due to the softening effect of the chair's temperature over the rings sealing the venting holes and to low flexural modulus of the thin section in the seating zone. Modifications had to be made again to the mould closing lip and different seals had to be found to withstand a wider range of temperatures.

It was also defined that - in industrial moulding conditions - it would be better to let the chairs stabilize their temperature and modulus briefly before inserting them in the foaming jig. A small buffer station between injection moulding machine and carousel would perfectly fit this need and compensate for minor differences between the injection moulding and the carousel's cycle times.



Picture 6: demoulding phase of the PP chair

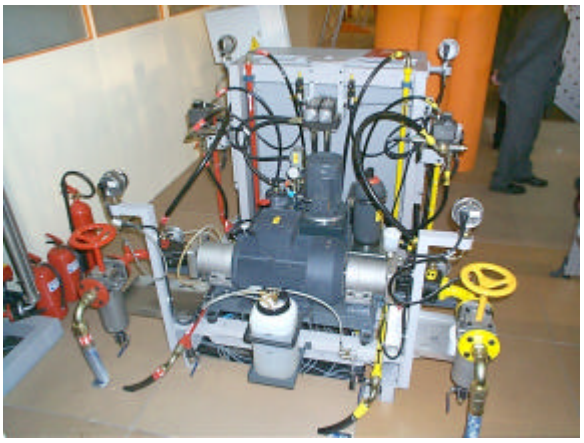
The temperature of the plastics insert would still provide the expected benefits in term of foam's flowability, surface aspect, cycle time and energy saving.

The performance at K '98

In spite of some minor logistic problems the whole production unit was up and running at the main World's plastics fair, on its opening day October 22, 1998 in Düsseldorf, Germany. *(Picture 6)*

The Sandretto Mega TE F 9208/100 with electric drive on the plastification screw produced one 3.2 kg chair in Polypropylene every 58 seconds; a Sytrama demoulding robot placed it near the revolving station, where it stayed to cool for a few minutes and was then revolved and transferred into the foaming station when this was ready to receive it. At this point the upper lid of the foaming press, holding the FPL mixing head, was automatically closing and the Polyurethane injection could take place.

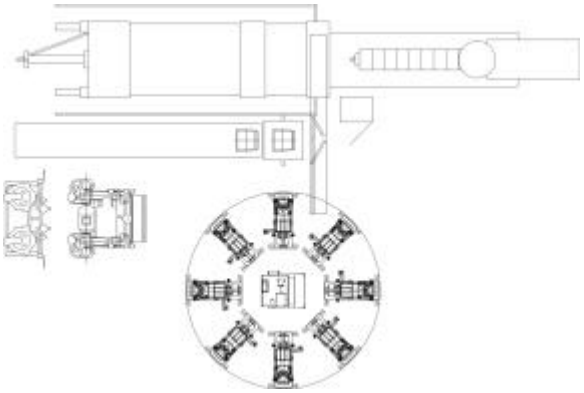
The Cannon "A-System 40" machine *(Picture 7)* dosed 390 g of black, integral skin formulation in the closed mould, and the expansion was filling the mould cavity and continued - in a very controlled way - through the venting holes drilled on the upper mould. After 4 minutes the press automatically opened, and the robot could demould the foamed chair and bring it to the revolving station, where it was turned by 180 degrees and placed on the outgoing conveyor.



Picture 7: the Cannon "A-System 40" high-pressure metering unit

The robot would then revolve and feed to the foaming station the next waiting chair. Differences in cycle time were compensated by placing the injection moulded chairs in a stack and picking them when requested.

A turntable- or carousel-based foaming unit would of course foresee a number of foaming presses equal to the Polyurethane foaming cycle time divided by the injection moulding one. *(Picture 8)*



Picture 8: turn-table solution for the foaming side

A similar configuration, with a number of presses placed in a row and one fixed mixing head on each mould, could provide a smoother start of production with few models and fewer parts per day. Adding more presses it will provide the same productivity of a turntable: an extra bonus in this case could be the simultaneous production of the foamed part in different colours, thanks to the use of one CCS (Cannon Color System) for each mixing head. Loading and unloading operations could be carried with a rail-mounted simple pneumatic robot.

Advantages and potential applications

A lot of interest was raised through the visitors, and some negotiations were initiated for this specific and other similar applications, confirming our opinion that these combined technologies do have a potential future. In this specific case the final product is a stylish plastic chair with an elegant integrated cushion. *(Picture 9)*

Picture 9: The finished garden chair (left) with a PUR integral skin foamed seat

The integral skin foam resists to surface scratches, abrasion, UV rays, liquid detergents and does not absorb water. It can be left outside and stacked without fearing damages to the seat, an ideal feature not only for private homes but also for outdoor public areas such as swimming pools, terrace cafés and clubs. The introduction of an IMC (In Mould Coating) system could enhance the resistance to UV and water, and provide a wider range of seat colours from the same production line.

The project is now under further development and industrialisation to optimise the manufacturing aspects and allow for multiple injections on the same chair: as some of the interested prospects put it “why limit the comfort to the seat?”, and “why limit the application to outdoor furniture?” Don’t you think that your back, and your arms too, deserve some more comfort when you are sitting on a plastic chair in a waiting room or in front of your computer?

Biography

Max Taverna - born in Buenos Aires, Argentina, in 1949 - has an education background in industrial chemistry. He worked five years for Upjohn's Polyurethanes Division in Italy, and joined Cannon Afros as European Sales Manager in 1982. Since 1986 he has co-ordinated all the Group’s communications activities, and is today Cannon Communication’s Director.