

## USER REPORT

Plonsk/Poland + Kottlingbrunn/Austria – September 2016

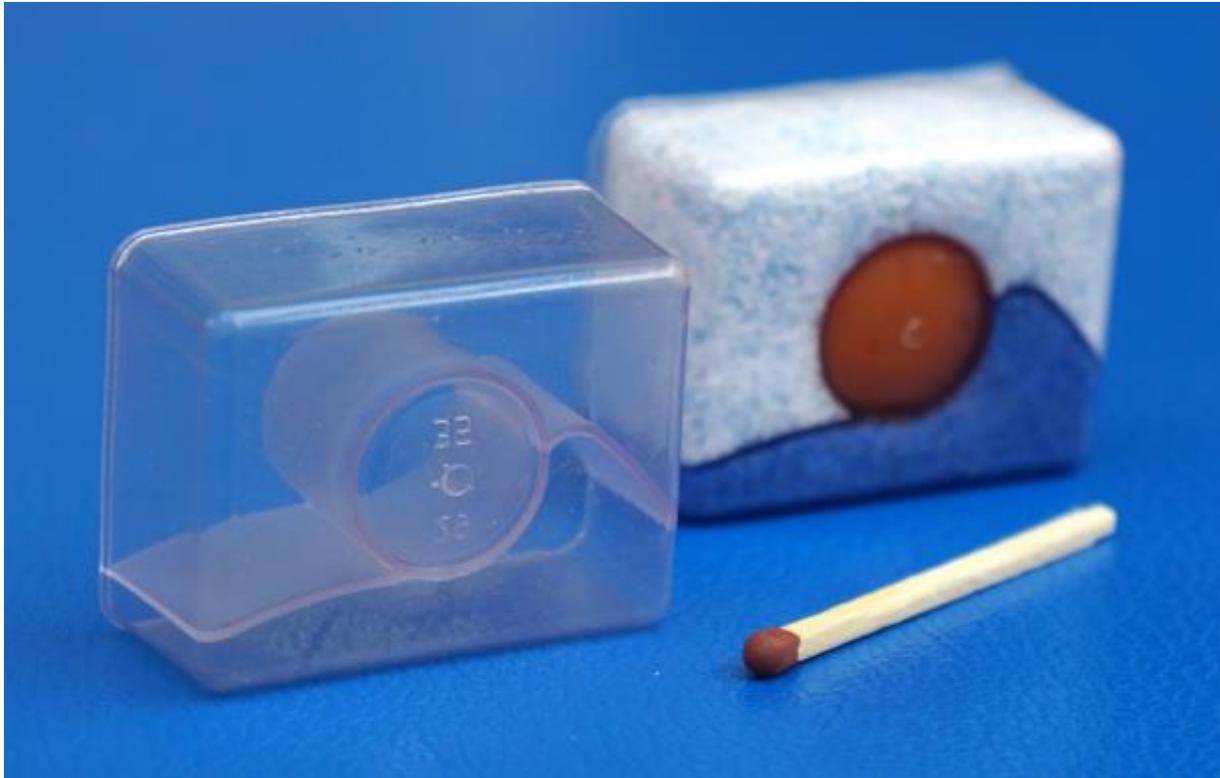


Photo: author

Fig. 1: Polyvinyl alcohol containers, resistant against acids and alkaline compounds, but soluble in water, are used in large numbers for laundry detergent applications.

## New ground broken and conquered

Polyvinyl alcohol (PVAL) is a plastic material little known so far. It offers the outstanding attribute of solubility in water with simultaneous high resistance to most contact chemicals. PVAL has been little known until recently, primarily because it could only be processed into film, but manufacturing injection-molded parts from it was not possible. The reason was its large variation in characteristic material values due to batch production. This changed, however, with the solutions discovered by the Austro-Polish injection molding company Buzek Plastic, which developed over a period of 10 years and in several evolutionary steps a mass production technology for making water-soluble, multi-chamber laundry detergent containers (Fig.1), of which it is now producing 1.3 billion units per year. The machinery and automation technology for this purpose have been supplied by Wittmann Battenfeld.

## **Polyvinyl alcohol, largely unknown in spite of unique attributes**

Polyvinyl alcohol (PVAL) was first produced in 1924 by the German chemists Wilhelm Hermann and Wolfram Hähnel and is thus one of the oldest types of plastic material. It is interesting to note in this connection that PVAL cannot be obtained directly from the vinyl alcohol monomer, but only by way of a hydrolytic reaction (also known as saponification) with sodium hydroxide from the even more ancient plastic material polyvinyl acetate (PVAC), which the chemist Fritz Klatte, also from Germany, had already produced for the first time in 1913. Just as interesting is the fact that both these plastic materials, although directly related to each other, have different attributes. Polyvinyl acetate is insoluble in water, butanol, diethyl ether, petroleum ether and aliphatic hydrocarbons, but soluble in low alcohol concentrations, numerous ketones, esters, cyclical ethers, and aromatic and chlorinated hydrocarbons. Polyvinyl alcohol is totally different: it is water soluble, but resistant to most anhydrous organic solvents.

Polyvinyl alcohol production can be controlled with the result of PVAC being transformed either entirely or only partly into PVAL. The more residual acetate the polyvinyl alcohol still contains, the lower its solubility in water. The varying acetate content also causes variations in melting point, melt viscosity and processing parameters. While the melting point for fully hydrolyzed PVAL is about 230°C, it ranges from 180 to 200°C for partly hydrolyzed types. The density ranges from 1.21 to 1.31 g/cm<sup>3</sup>, depending on the type of material.

What both plastic materials have in common compared to other plastic materials, is the shorter length of their polymer chains. It ranges from 100 to 5000 and fluctuates from one batch to the next, depending on process conditions. The resulting mechanical properties of PVAL also depend on its water content, since water diffused into it acts as a softening agent. Therefore PVAL loses some of its tensile strength but gains in elasticity with high atmospheric humidity.

Moreover, PVAL is an excellent film formation agent with good wetting properties. Consequently, watery solutions are processed as ingredients for glues or adhesives and for thickeners in hair sprays or shampoos. They are also used as additives in paper processing, or as mold release agents in the production of fiber composite parts, which can subsequently be rinsed off. In PET bottle production, PVAL is used as a CO<sub>2</sub> barrier layer. It is also quite common in film production, for example for packaging bags intended to be dissolved. Somewhat more exotic are forensic applications, where pads with layers of PVAL are used to track traces of gunpowder.

## **PVAL injection molding = breaking new ground**

Throughout its history of almost a century, polyvinyl alcohol melt has hardly ever or never been processed by injection molding. The main reasons were a lack of product ideas as well as fluctuations in material key figures by up to plus/minus 20 per cent.

This was the starting point in 2003, when a multi-national chemical company made an enquiry at Buzek Kunststoffverarbeitung in Austria about production equipment to manufacture injection-molded single portion packages for dishwashing granulate. Andreas Huber, Managing Director and CEO of Buzek Holding GmbH in Austria and Buzek Plastic Poland, recalls: "New technical challenges in terms of injection molding processes have always fascinated me. Here, the foundation was laid while I was still Product Manager for Special Materials at Battenfeld. I could hardly believe that nobody had yet succeeded in manufacturing mass-produced parts from polyvinyl alcohol. This only became clear to me after the first plasticizing tests, for the results were very similar to wallpaper paste. So the material stuck firmly to the mold. It is not surprising that polyvinyl alcohol is found in every paper glue. Now I knew that the road to series production would be a long one. But on the other hand, I also suspected that if we succeeded, the product would have an enormous potential. So today, I am very glad that my business partner Günter Buzek and I were also able to gain the cooperation of the Battenfeld management for this project. Their giving it the green light meant that we were jointly able to start the systematic development of an appropriate application technology."

Following several preliminary tests, a low-viscosity type of PVAL originally developed for the paper industry emerged as the basis for an injection-moldable type of feedstock. It was the starting point from which a material compound which could be processed was developed in an iterative series of tests with various auxiliary additives for processing. Once this compound had been created, the company successfully produced the thin-walled 30 x 40 x 15 mm container (Fig. 1) first with a single-cavity mold, then a 4-cavity and finally a 12-cavity mold. Tests at the Battenfeld technical lab on the all-electric injection molding machine models BA 1000/500 CDK-SE and EM 1600/350 revealed that fast injection and high-precision injection pressure control would bring about the break-through, even though reject rates of about 15 to 20 per cent still had to be accepted, due to batch-related fluctuations in material data.

### **Application technology becoming a project in its own right**

In the course of testing, it became obvious that PVAL processing required significantly more expert knowledge than could be expected from a newcomer to injection molding production such as the chemical company which had made the enquiry. Consequently, Andreas Huber decided jointly with another former Battenfeld colleague by the name of Günter Buzek, who had been operating an injection molding plant of his own since 1999, to present their offer to the chemical company for handling the production as a sub supplier. They still maintained this offer, even when the negotiations were no longer about delivering supplies from Austria, but about the construction of an "in-house production facility" at the company's Polish filling plant, and they established Buzek Plastic Poland Sp.z.o.o. in May 2005. Using three hydraulic HM 270/1330 machines from Battenfeld with rechargeable injection batteries, the leap from a 12-cavity test mold to 32-cavity hot-runner molds was made, and series production was started. In spite of numerous "outliers" among material data and consequently high reject rates, the production got under way. The key factor was a situation-

related production method, which consisted of manual parameter adjustment based on continuous observation of the material's behavior and included 100 per cent visual inspection of the finished parts by operating staff on every machine.

### **2005: evolutionary stage II, 32- and 64-cavity production cells become standard**

After about another year, the process technology and composition of the material compound had been stabilized to the point where a further increase in production capacity could be considered. As the product design was not altered for the time being, the cycle time remained unchanged at 28 seconds, with a scrap rate of about 15 per cent. What had to be further improved though, was the method of visual parts inspection. Instead of separate inspection on every machine, a multi-track parts transfer system was installed, to which several machines were connected, and which transported the parts to a central inspection station where every single part was still inspected by human staff.

In 2008, the production routine of the Buzek team had been stabilized to the extent that the number of cavities could be doubled once more, this time from 32 to 64. However, the aim was not only to double the number of cavities, but also to combine this with a reduction in cycle time. To provide the necessary prerequisites, the molded part was re-designed in close cooperation with the customer's engineers, with a selective reduction of wall thicknesses which led to a 15 % decrease in both part weight and cycle time. But this required larger and faster machines. Because of positive past experience, Battenfeld was again selected as equipment supplier, and the hydraulic models chosen were HM 400 / 2250 machines, again with rechargeable injection batteries, including Battenfeld robots and parts transfer systems. The result of this evolutionary stage was impressive: within only three years from production start-up, the company had increased production output by 300% and simultaneously reduced the scrap rate from 15 to 9 per cent. The high output volume forced the company to create a new concept for quality inspection of the finished parts. This was no longer feasible using human staff, neither economically nor in terms of available human resources. To solve this problem, the Buzek team installed a supporting visual inspection system with automatic separation of rejects. A mere supporting system, because it was able to recognize only the parts' general completeness, but not every defect in minor details.

### **2013/14: evolutionary stage III, a new plant according to the Industry 4.0 concept**

In 2012, when the space available at the in-house production facility was fully utilized by 19 production units and further growth rates were planned, Buzek Plastic decided to build a new, additional production facility outside the customer's plant. The latest production methods were to be implemented, unencumbered by existing structures. The guiding principle was the desire for complete networking of data across all production steps, with an additional facility for automatic control within pre-set quality tolerances, as described in Industry 4.0 concepts. The central idea was to create an automatic zero-reject system by automated interaction between the various production steps. (Fig. 2).

The Managing Director of Buzek Plastic, Andreas Huber, explains: "After we had communicated our wishes and ideas to several machine manufacturers, we finally found again the right partners in the Wittmann team, which is open for innovation.

Thanks to their extensive production centered around injection molding machines and their pioneering work with interface technology (Wittmann 4.0 system), our concept of a production plant regulating itself within certain limits was not dismissed as a kind of utopia, but realized step by step together with us".

Parallel to the plant design, a re-design process was initiated in close cooperation with the container customer, whose agenda included a product cost cut by way of a further reduction in weight and significant shortening of the cycle. To cut a long story short: these targets were reached in the form of 10 per cent less weight (with external dimensions remaining unchanged) and an expected 25 per cent shortening of the cycle time. But with all of this, the capacity of the hydraulic machines was stretched to the limit. Consequently, a changeover to servo-electric injection molding technology presented itself as the only sensible alternative. However, such aggregates were not yet available in the required size. Therefore, some additional development work had to be done in this area too. In a lively dialog between Andreas Huber and the Battenfeld engineers, the development of the performance specifications was addressed, which were then realized for the first time in the form of the hybrid machine model *MacroPower E 450/2100*, with a hydraulic 2-platen clamping unit with 450 tons clamping force and a servo-electric size 2100 injection aggregate (Figs 3 to 5).

Each injection molding machine was transformed into a production cell by adding a linear robot and a revolving pallet transfer system for finished parts photography with integrated parts inspection and handling stations. Of special significance is the vision system for part quality assessment, adapted to the drastically increased production quantities and quality requirements. Now, equipped with 12 cameras and a mirror system and synchronized with the cycle, it takes photos of every one of the 64 finished parts from five directions and passes these on to the downstream analysis system. This system's software is able to detect 23 different kinds of defects (Figs.6 and 7). Faulty parts are sorted out by a pick-and-place handling device and replaced by good parts from a parts buffer immediately following their passage through the photo station. This ensures that only 100 per cent good parts are passed on to the automatic packaging station (Figs 8 and 9). Within the peripheral parts handling system, all finishing stations communicate with each other according to a specially developed logistics algorithm to compensate fluctuations in capacity.

On the whole, the performance level achieved at the new plant is something to be proud of. Not only was the output per injection molding cell increased by more than 400% within eight years, but the scrap rate was reduced from originally 15 per cent to now less than 3 per cent as well.

### **Evolutionary stage IV in view**

Now all fully automatic production cells at the new plant are once again utilized to 100%. The next evolutionary step is replacing the older equipment on the in-house production floor by additional production cells at the new plant. Again this not only involves another increase in capacity, but also another rise in efficiency. Thanks to latest innovative design adjustments which will enable a further reduction in product weight, there are realistic prospects of another 300 per cent increase in productivity.

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### **About WITTMANN BATTENFELD**



WITTMANN BATTENFELD is a company of the WITTMANN Group with its headquarters and production plant in Kottlingbrunn / Lower Austria. The company focuses on plastics injection molding technology and covers the entire machinery portfolio, ranging from micro injection machines with 5 and 15 t clamping force to large machines with 2,000 tons clamping force. Extensive additional technology packages, such as special equipment for multi-component, foam or fiber composite injection molding, round off the company's product range. In combination with the range of the WITTMANN Group, a leading supplier of robotics and peripherals for material feeding, WITTMANN BATTENFELD is able to supply complete injection molding lines including Industry 4.0 data networking.

Further information is available on [www.wittmann-group.com](http://www.wittmann-group.com)

## About BUZEK PLASTIC POLAND SP Z O O



Buzek Plastic Poland based in Warsaw is a member of the BUZEK-HUBER group. The company was established in 2005 and is currently the world market leader in processing water-soluble plastics by injection molding.

The company's origin is an in-house production facility inside the Polish plant of an international chemical company. In cooperation with this company, methods of injection molding water-soluble plastics were developed and patented, and used by Buzek Plastic exclusively for this company's parts production. In 2013, a new production plant according to Industry 4.0 standards was opened in Plonsk in addition to the in-house production facility. Buzek Plastic Poland's second business area apart from injection molding is the development of new fields of application for water-soluble plastics for other industrial purposes.

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## Illustrations:



Fig. 2: The production plant of Buzek Plastic Poland in Plonsk, which was built following the principle of data networking according to an Internet 4.0 concept.



Photo: author

Fig.3: Andreas Huber, Managing Director of Buzek Plastic, in front of the operating panel for material feeding.



Photo: author

Fig.4: Production cells around a WITTMAN BATTENFELD *MacroPower* E 450/2100 are used in production. Their high-speed injection capacity combined with high positioning accuracy offers the necessary prerequisites for injection molding of polyvinyl alcohol.



Photo: author

Fig. 5: 64-cavity hot-runner molds are used in production



Photo: author

Fig.6: Every workpiece carrier passes through a vision control station (shown at the bottom on the left) for automatic scanning of every molded part from 5 directions



Photo: author

Fig. 7: The quality management system is able to take and analyze 5 pictures of every molded part. For this purpose, 12 cameras plus an additional mirror system are used. The system is capable of shooting 64 x 5 pictures within the machine's cycle time! The analysis system connected with it has been set to identify 23 different potential defects.



Photo: author

Fig.8: Pick& place handling devices subsequently sort out all parts identified as scrap and replace them with good parts (see good parts buffer at the center above the handling station).



Photo: author

Fig.9: From the transfer pallets, the molded parts are deposited in transport trays inside shipping boxes and then passed on to the filling machine of the laundry detergent manufacturer.