Searching for the Perfect Dew Point

Drying. During production of technical parts subjected to high loads, varying amounts of residual moisture in the material cause a decrease in important mechanical properties. A drying system with automatic temperature and dew point leveling, combined with control of the air flow, addresses this issue.

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Theo Hillers GmbH, Kall, Germany, received the order to produce a clutch slave cylinder from an automotive supplier. The complex component had to satisfy both mechanical and appearance requirements. For instance, internal pressures between 40 and 50 bar are common during operation. For safety reasons, however, the burst pressure is specified as several times the operating pressure. Hillers produces about 4,500 of these components daily on two injection molding machines. The material processed is a semi-aromatic polyamide (PPA) with 50 % glass fiber content from Ems-Grivory. The material is supplied vacuum-packed in octabins.

"The molds were built, sampling completed successfully – volume production could begin", recalls Erich Klinkhammer, production manager, "but production had hardly started when we encountered difficulties; we were not always able to achieve the required burst pressure".

Many processors are probably familiar with such situations. The search for the reasons usually follows a routine. In this case, the Hillers team concentrated initially on the temperature control and injection parameter settings. The mold was also examined closely; it was assumed that the valve gates might be damaging the material. Troubleshooting also focused on the plasticating unit of the injection molding machine. Screw, screw tip, screw geometry, melt temperatures (again), hot-runner system and valve gates were examined, monitored and varied.

"We literally stood everything on its head", commented Dirk Hensel, plant manager at Hillers. The customer sent specialists to assist us. "All parameters were recorded, documented and evaluated, every deviation questioned no matter how small", stated Hensel in his description of the situation.

After almost every aspect of the machinery and equipment had been investigated, only the material remained as the cause. Material and drying experts joined the team – and additional measurements followed. In the meantime, it was noted that testing of the burst pressure at higher drying temperatures yielded better results. As a result, suspicion shifted to the dryer as the cause.

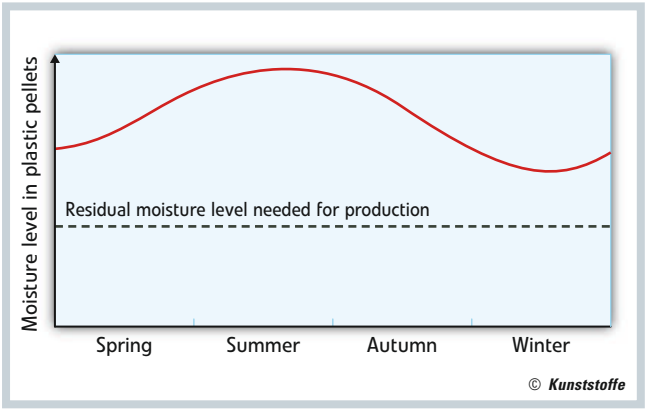

Fig. 1. If plastic pellets are stored in ambient air, they slowly approach the moisture level of the surroundings until the moisture levels in the material and surroundings are in equilibrium

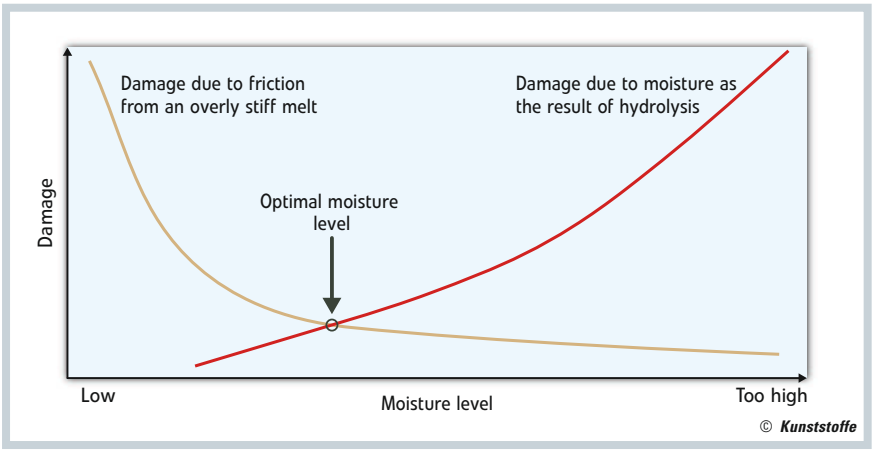

Fig. 2. The moisture level has a direct effect on the viscosity of the melt, degradation is kept to a minimum only at an optimal moisture level (figures: Motan-Colortronic)

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Fig. 3. The perfect dew point found through a joint effort: Georg Klink (left) from Motan-Colortronic and Erich Klinkhammer from Hillers

"For two weeks, we took a material sample daily in order to measure the moisture content", stated Erich Klinkhammer in his description of the subsequent procedure. "We established that the material in the octabin was sometimes too moist, exceeding the capabilities of the dryer. With this knowledge, we extended the series of measurements and continued recording the moisture level of the material in the octabin at regular intervals." It became apparent from these recordings that the material in the open octabin absorbed moisture very quickly . At the same time, it was observed that the residual moisture in the dried material also varied, and was apparently related to the residual moisture in the octabin **(Fig. 1)**.

Burst pressure tests at various residual moisture levels followed. These data were then compared with the settings. A correlation between the burst pressure and injection pressure was found: the resulting burst pressure declined along with the injection pressure. Next, these data were compared with the data for the particular material batch shot after shot and the residual moisture as well as the flow number observed. This led to the discovery of a relationship between batch changes and a jump in the burst pressure: At a relatively high flow number, higher burst pressures were observed – the burst pressure values dropped at lower flow numbers.

"There were also limits, however", stated Dirk Hensel. "If the material was too dry, the burst pressure was OK, but we then had problems with the surface quality." The reason is that the moisture level directly affects the viscosity of the melt **(Fig. 2)**. Too little residual moisture results in a stiff melt and greater shear on the material during plastication, degrading the material and decreasing the viscosity.

Too high a residual moisture, however, results in breakdown of the molecular chains and lower mechanical properties. This explains the poor results from the burst pressure tests.

From his measurements, Klinkhammer established that at 23 °C and 50 % humidity, moisture uptake by the PPA can increase to 1.3 %, and even to 1.7 % depending on the weather. It is enough for the material to be in an open octabin over the weekend under the correct weather conditions.

The specifications for the drying equipment initially assumed a guaranteed initial moisture level. The high residual moisture under unfavorable conditions, however, meant that the dryer could not dry the material in the required period of time, since it is not practical to dry material with an initial moisture level of more than 1 % to a residual moisture level of 0.03 % with an adsorption dryer. Depending on the throughput, appropriately sized, large desiccant dryers and drying hoppers need to be installed. A deciding factor in this regard is also the associated high energy requirement.

Accordingly, the objective at Hillers was to achieve a stable residual moisture level that was independent of the throughput. It was absolutely necessary to prevent overly 'wet' material from entering the dryer in order to ensure adequate time for drying to the required residual moisture level.

The optimal residual moisture level was specified as 0.03 %. Since the material in the as-delivered condition of about 0.05 to 0.08 % is almost dry enough for processing, this condition should be 'retained as long as possible' – without degrading the material!

Fig. 4. Fitted with automatic temperature and dew point leveling (ATTN), the Luxor A 120 dry air generator controls the dew point of the process supply air with an accuracy of ±1 °C

"Process Stability Means Having all Accessible Parameters under Control"

Motan-Colortronic GmbH, Friedrichsdorf/Taunus, Germany, was now brought in. "First we defined the overall conditions", stated Georg Flink of Kunststofftechnik Flink und Wortmann GbR, Burscheid, Germany. As a sales partner of Motan-Colortronic, he provided the interface between Hillers and the applications technology center of the material handling equipment manufacturer in Friedrichsdorf **(Fig. 3)**. The specifications called for supplying two machines with material at an average of 15 kg/h, i. e. the dryer had to dry a maximum of 30 kg/h. The machine operating times also had to →

! Company Profile

Theo Hillers GmbH, Kall, Germany, is a classical supplier company. Some 90 % of the production is destined for well-known Tier 1 companies in the automotive industry. The company specializes in manufacturing demanding technical parts such as filters for fuel delivery units, climate control systems or components for clutch hydraulics. Many of these parts were previously manufactured by means of aluminum die-casting. Additional products include medical and installation equipment.

With a total of 80 injection molding machines having clamping forces from 250 to 5,500 kN, Hillers produces parts with weights ranging from 0.1 to 400 g. The materials processed are primarily PA, PP and POM; daily about 7 t on 250 days per year.

At its headquarters in Kall, the family-owned company, founded in 1980, currently has a workforce of 210 employees. Since 2006, Hillers has also had a production facility with 45 employees in Györ, Hungary. In Neustadt/Wied, Germany, Hillers also maintains a specialty machine manufacturing operation with seven employees.

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Fig. 5. To address renewed uptake of moisture by the material in the octabin, the container is covered. In addition, its content is maintained under a permanent blanket of dry air

be taken into consideration, i. e. whether both machines were running, only one or, in the worst case, none.

The dryer was designed to provide a residence time of eight hours for the material when both machines were running. The eight hours, however, applied only if the material entered the dryer at a maximum of residual moisture level of 0.08 %. If, on the other hand material within the initial moisture level of 1 % had to be dried to the agreed-upon residual moisture level of 0.03 % for processing, the eight hours would not be adequate. It was necessary to find a solution that would keep the residual moisture level of the material in the octabin at the as-delivered level.

The specific task of Motan-Colortronic was now to assure a defined, reproducible residual moisture level. For this, it was necessary to determine a suitable combination of dew point temperature and drying temperature, for which extensive drying trials accompanied by numerous moisture measurements were conducted in the technical center at Motan-Colortronic.

In principle, such an equilibrium state involving different parameter combinations is possible. However, in order to prevent thermal degradation of the material at long residence times in the drying hopper, a combination of low drying temperatures and better (lower) dew points is recommended. It is unavoidable that at lower drying temperatures the drying time becomes longer. For a technically and economically practicable system design with constant drying parameters, limiting the permissible initial moisture level was essential.

To meet these requirements, the system at Hillers was fitted with automatic temperature and dew point leveling (ATTN) and optimized on the basis of the knowledge gained in the technical center. ATTN was developed specifically for applications where the material drying must take place within only a narrow dew point temperature window. The dew point of the process supply air is controlled accurately and held constant with a control accuracy of ±1 °C as well as documented. As the dry air generator, Hillers uses a Luxor A 120 with Eta-Plus technology and a dry air flow rate of 120 m^3/h. The Luxorbin A 600-SH drying hopper has a capacity of 600 liters **(Fig. 4)**.

Eta-Plus combines control of the dryer's air flow rate with lowering of the drying temperature. The system recognizes changes in material throughput by means of the discharge air's temperature and lowers the air flow rate when the temperature increases. If the temperature nevertheless continues to increase during interruption of production, the system additionally lowers the drying temperature to a standby temperature. The interplay of all components assures fully automatic, reproducible drying on the basis of individual conditions.

To address the residual moisture level of the material in the octabin, the drying experts came up with a relatively simple countermeasure: the content of the now-covered container is maintained under a permanent blanket of dry air by means of a small, economical air dehumidifier **(Fig. 5)**. Both this air dehumidifier and the dryer continue running on days when there is no production, the dryer, however, at greatly reduced output, i. e. at a minimum temperature and air flow rate.

A decisive factor in this regard is also a correct calculation of the amount of material needed on the machine. If this amount is too large, there is the risk of renewed moisture uptake there. For safety's sake, Hillers installed small machine-mounted dryers that can be used when

Fig. 6. For safety sake, Hillers is installed machine-mounted dryers that can be used as necessary to prevent renewed uptake of moisture by the material pellets on the machine

necessary **(Fig. 6)**. For longer interruptions or on the weekend, the hopper is nevertheless emptied. Up to two hours, however, can be handled without difficulty.

Conclusions

Decisive for successful completion of the project was the close, interdisciplinary cooperation of the experts involved. When the individual processes were observed, all parameters appeared to be OK, but the end product was still faulty. It was only after the experts sat together at one table and the numerous trials had been run and evaluated that a solution evolved. Critical here were not least the trials conducted at the Motan-Colortronic technical center, the results of which were incorporated into the design of the drying system with temperature and dew point leveling. ■

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