Making the Cut—Innovations in Plastics Pelletizing

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Over the past half century the number of pounds of plastics processed has grown from 2 billion pounds per year to 200, and nearly all that plastic has to be pelletized, sometimes two or three times. Twin demands have emerged of the pelletizer—make more pellets in a given time while also making them more consistent. Some examples, 1) bottle resin producers must make their product within a very narrow size distribution range, with the pellets being cylindrical and remaining in a nominal weight range of 17-25 mg; 2) color compounders must produce product that is free of fines and color cross-contamination, and 3) micropellet producers have to control the size distribution while increasing throughput.

In response to these increasing demands, manufacturers of pelletizers have developed broadly in two directions, refining and expanding the cold pelletizing options while at the same time developing hot face cutting. Each system has its strengths and weaknesses.

Plastics pelletizing grew out of rubber processing technology: Two-roll mills into waterbaths, into dicers that pulled and cut the web into pellets. In the early 1950s Fredrick Roddy at Cumberland developed the first domestic pelletizer. From that time to now, the pelletizer has continued to evolve, so that now the family tree looks something like Figure 1.

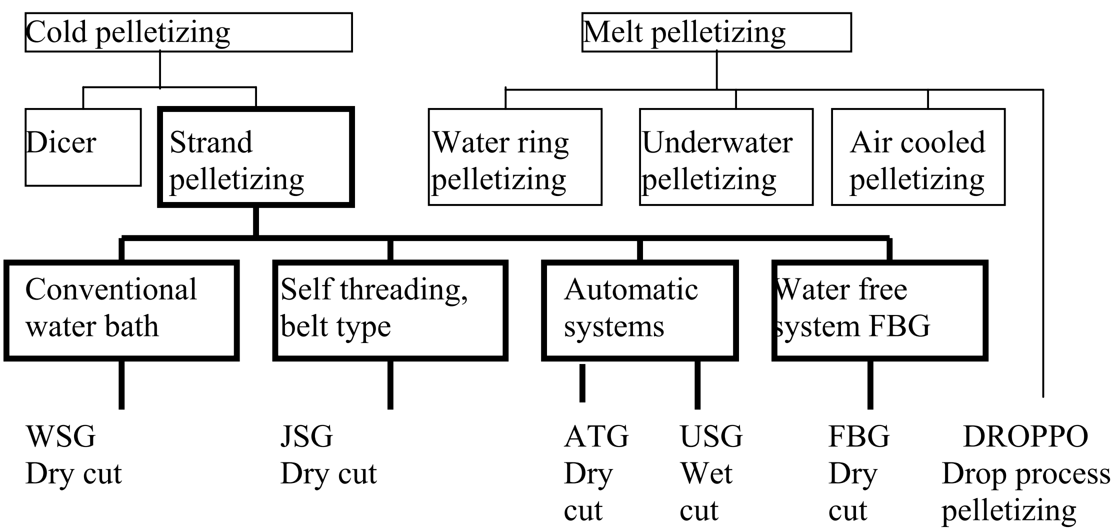

Figure 1. Pelletizing Family Tree.

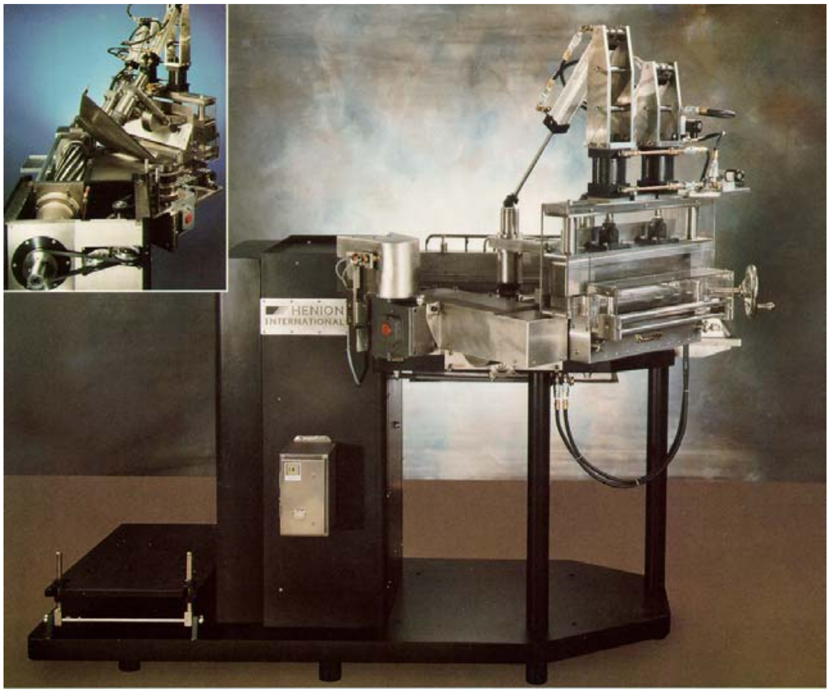

Figure 2. Dicer, From Henion.

Roddy's innovation was simply to divide the web into strands and then to replace the stairstep blades with straight knives that cut against a bedknife. Given the venerable nature of cold pelletizing the technology has undergone improvement incrementally, focusing on ease of turn-around, pellet quality, power, safety, and noise reduction.

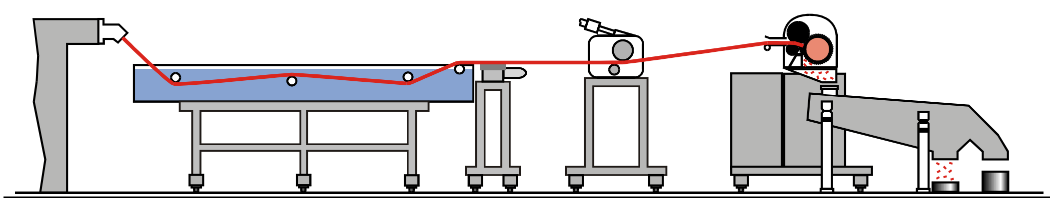

Figure 3. Typical Strand System.

Quality control programs demand quick and verifiable cleaning procedures, so as such programs have been implemented over the past couple of decades the strand pelletizer has also been upgraded to permit tool-less disassembly and rapid cleanout. Nearly all vendors now permit access into the cutting chamber without recourse to tools. Removable feedrolls, even if driven, are now standard. Additionally, most horizontal surfaces inside the cutting chamber have been beveled to prevent the accumulation of pellets on those faces.

Figure 4. Cutterhead showing beveled surfaces.

Figure 5. Open cutting chamber showing removal of upper feed roll and swiveling stripper.

Rotor Technology

Manufacturers have replaced the straight, replaceable blade rotors with helical, solid body types. This accomplishes two objectives—the continuous cutting action quiets the machine while the helical tooth slices into the strand more slowly, providing a cleaner cut, and the cleaner the cut, the fewer fines produced.

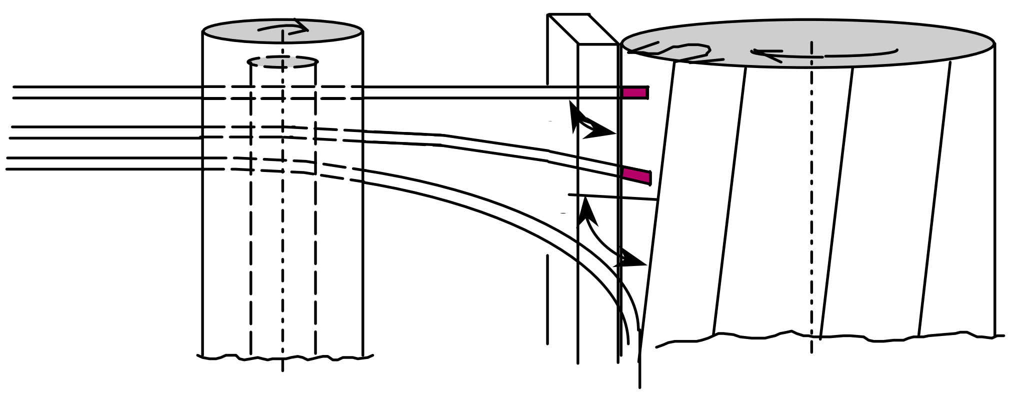

Figure 6. Helical Effects

The number and type of helical rotors have steadily increased, so that today rotors of various materials and with different helical angles are available. Helical rotors bring with them some trade-offs, however. The initial action of the tooth tends to „scissor-cut“ the strand pushing it away from the tooth at low speeds, and when running at high speeds the helical angle tends to turn the strands in the direction of the helix. While shortening the relief land on the back of the rotor tooth fixes the latter problem, often this correction goes unnoticed.

We think of the rotor as a rigid, unyeilding metal piece, and of the strands as soft, easily cut plastics. But just as the tooth presses on the strands, the strands press back on the tooth. If strands agglomerate in the center of the rotor, it wears prematurely. By working the tooth back and forth, the metal begins to fatigue, crack, and corrode due to this deformation. In those cases where strands are very hard and abrasive the usual recommendation is to go to a tungsten carbide rotor. Tungsten carbide rotors are less prone to metal fatigue and wear, but the material is expensive, brittle, and very hard to work. The earliest such rotors provided for a solid tungsten carbide blade bolted onto a rotor body. Later, long strips of the metal were clamped into a rotor body using wedges.

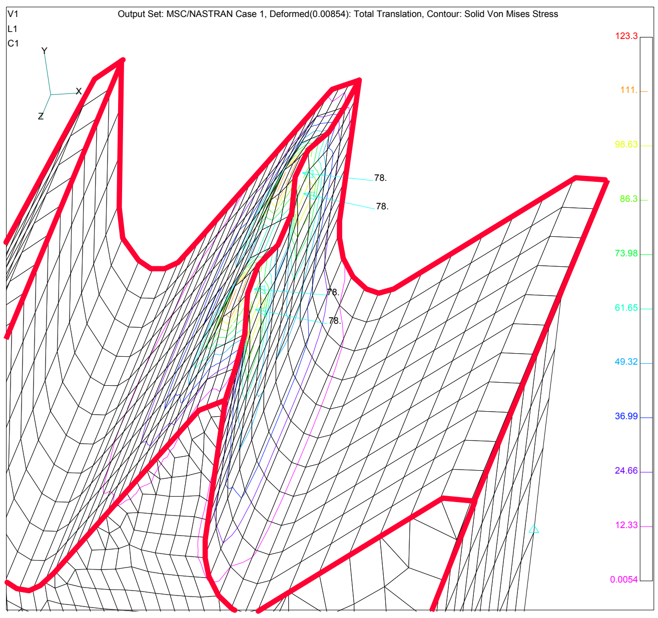

Figure 7. Deformation of tooth under load.

The latest development is the Meister rotor, which uses locking pins inside recessed blades in rotor segments. This prevents the blade from slipping out of the rotor body, as can happen with the older wedge-lock design. High loadings of glass-fibers cause high impact forces on the blade, which can tear itself out of the rotor. The positive interlocking of the tungsten carbide blades that utilize screw collets into the rotor body prevents such catastrophic failure of the rotor. Since the rotor body can easily come into contact with pellets after cut, abrasion of this item can be reduced using a nitrided steel.

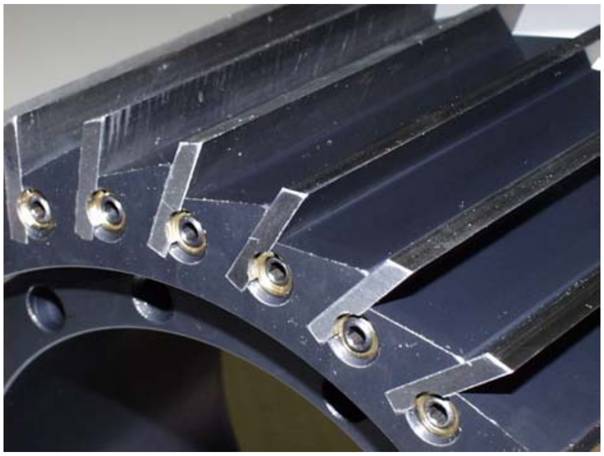

Figure 8. Meister Design with locking collets.

Wear Coatings

Since pelletizing is a kind of mechanical processing it involves friction, abrasion, and corrosion. Every part of the machine that comes into contact with either strands or pellets is exposed to wear, especially with rigid materials or abrasive additives like glass fibers. Different options of wear protection have been used, all of them aiming to increase the lifetime of the machine parts. The newest development in terms of wear protection is a stellite based surface coating, applied by high speed injection to metal surfaces. This innovative wear protection has been applied in some dry cut strand pelletizers that are producing 50 % glass filled PA-based compounds. In the inital trial, all the major parts of the cutting head coming into contact with either strands or pellets had been coated. After a period of several months, under normal conditions these parts were inspected for signs of wear. None of them showed measurable degradation, the only visible sign was some mirror-like polished areas on some surfaces.

Figure 9. Wear protection type VS 22 after several months of production.

Based on these encouraging results, we now recommend this type of abrasion protection for any application with materials or ingredients that can generate excessive wear. The payback in terms of lifetime and reduced service cost is quite convincing.

Developments in Bed Knives

Several new types of bed knives have appeared lately—upgraded tungsten carbide, different kinds of ceramics, and even diamond. As is always the case, the best materials also cost the most. PCD (polycrystalline diamond) is a hybrid piece constructed of tungsten carbide with an insert of PCD. The cutting edge itself consists of a sintered diamond layer that is bonded to a tungsten carbide substrate via a ductile intermediate layer. It is produced of uniform sized and extremely clean micro-grains sintered under high pressure and temperature. PCD-elements are available only in small dimensions. For bed-knifes, a length of several hundred mm can be achieved by hard brazing of PCD-elements to a supporting metal holder. Out of wear resistance considerations, the supporting holder is made of tungsten carbide. This combination gives impressive results—up to ten times the life of regular knives. However, the high price demands for very careful handling, especially taking into consideration the susceptibility to brittle fracture under impact loads. In combination with a tungsten carbide rotor, as described above, and using a properly set cutting gap, life-time of both cutting tools can be expected to be even better. After production runs of three months with GF-reinforced PA (up to 50% GF) under these conditions, a tolerable amount of wear was visible, but was almost not measurable.

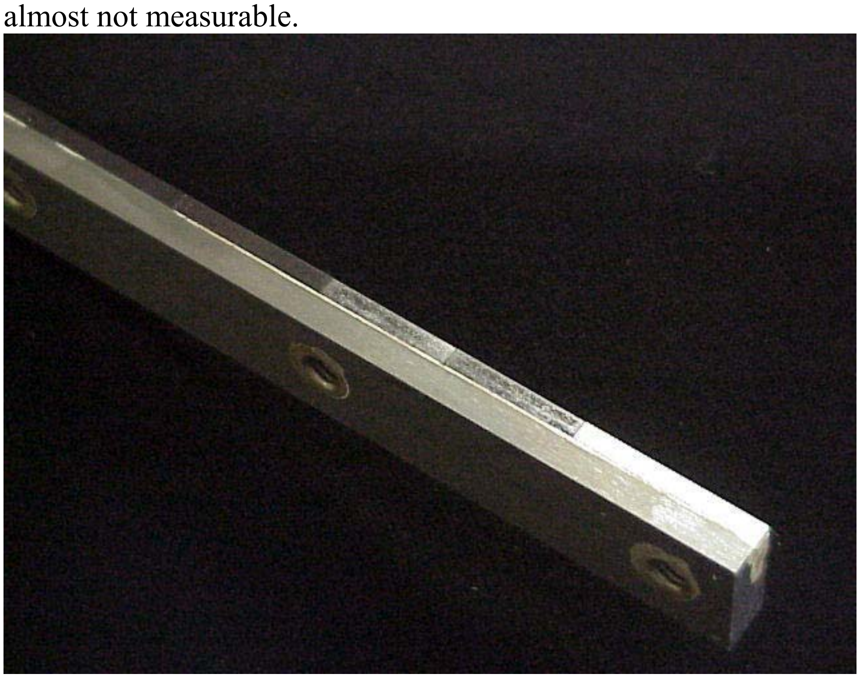

Fig. 10. Bed knife with PCD cutting edge.

Self-Stranding Systems

The traditional dry cut strand pelletizer gave rise to several variants. First among them is the waterslide, or USG.

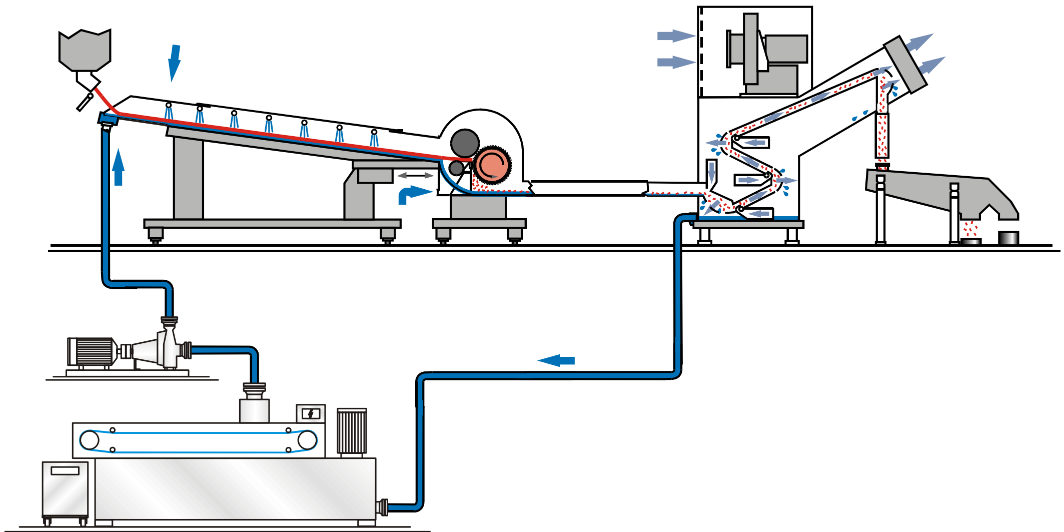

Figure 11. USG Schematic.

"Automatik Maschinenbau" built the first underwater strand pelletizers (USG), almost twentyfive years ago. Some of the very early machines are still in production. The newest versions, the M-USG, have intake widths up to 1200 mm, in either horizontal or vertical configuration, and are capable of up to 20 metric tons/hr throughput. These newer iterations incorporate quick exchange cutter heads, easy access to both the die-head and the cutting head through retracting segments of the sluice, minimized footprint, and consistently good pellet quality by reduction of the unguided length between the feedrolls and the cut point.

The USG process's advantage is its self-threading nature. Strands exiting in a vertical direction fall on a sheet of water, which travels down a sluice and into a cutter head, where the „skinned" strands are cut into pellets and then flushed into slurry. From there they remain in slurry only long enough to cool down to the point that they will not fuse together after drying. The advantage of the process is that the startup and running of the machines is automated; the disadvantage is that the sluice length and aftercooling times must stay within a given process window. The machine has found its greatest application in the processing of virgin polymers at high throughput.

Figure 12. MUSG 900 Horizontal.

For highly filled applications, the dry-cut machine or ATG is often the best choice. It relies on the same residual heat from the pellets to drive off any moisture left from the cooling bath, but it never immerses the pellets in water. The basic concept is to immerse the strands only long enough to put a shell on them, then cut them hot. Both the USG and the ATG work from the same principal--residual heat from the core of the pellet drives off moisture from its surface. In the case of the USG, the pellets are then washed out of the cutterhead with overflow water and remain in slurry until they go through a dryer. The ATG pellets are discharged from the cutterhead and are blown by an air conveyor to an elutriation bin and from there to storage.

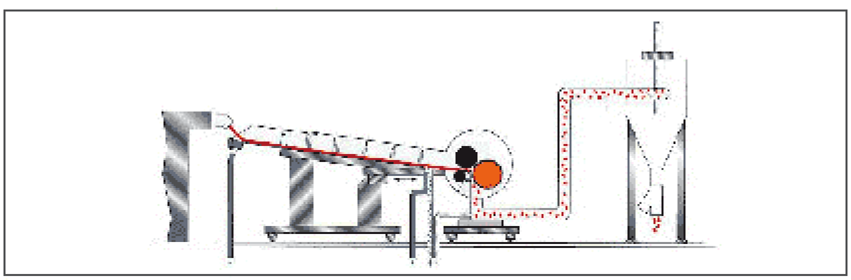

Figure 13. ATG Schematic.

Normally one can achieve a .2% retained moisture level under typical running conditions. To get some idea of the relative cooling time prior to cutting, consider that waterslides usually have only very brief residence times in the waterbath prior to cut—usually a second or two. Given that the strands cannot move slower than the water flow, nor can the slide be much longer than 5 meters, the process parameters require that the machine be built to narrow specification. Therefore USG machines are best adapted to virgin polymers with high throughputs; ATGs on the other hand are designed for highly filled applications.

Self-stranding Dry Cut Machines

Yet another varient is the belt type machine or JSG. The process involves utilizing a waterslide to gain self-threading advantages, then a belt up into a pelletizer to provide adaptability. Given that the waterslide's biggest disadvantage is its reliance on drop height, and that most compounding applications have only the extruder's die height to start with, the JSG was developed so that a self-threading system could be applied to compounding applications. Both the sluice and the belt provide positions so additional spray bars can be attached to the belt and sluice. The JSG also has recently come to the attention of compounders looking for high throughputs as well as adaptable design. The latest iteration of this machine is 900mm wide and runs 8.5 metric tons/hr. It is outfitted with an air injector into the pelletizer, in order to pick up any strands that would otherwise not feed into the machine automatically, as well as a unique through-the-belt airknife that helps pin the strands against the belt for better conveying while at the same time dewatering them prior to cut.

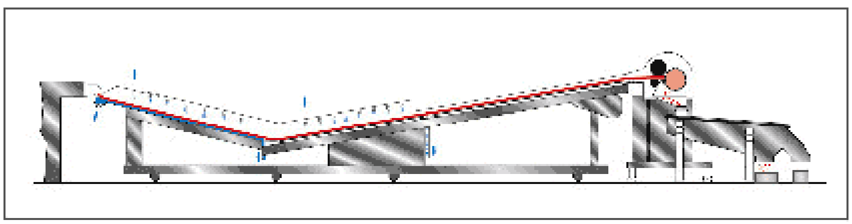

Fig 14. Layout of self-threading, belt type system JSG.

In some cases the strands cannot get wet at all. Usually these are speciality polymers that are soluble in water. In those cases we recommend the FBG in which the strands ride on a cushion of air. The advantage of such a system is that the product stays perfectly dry and does not stick to a conveyor mechanism. This is especially valuable when the polymer is tacky. The disadvantage is that it is not a fully automated system and, because the strands have to be seperated quite far apart, the strand count is limited to thirtyseven. Typically the maximum throughput is 5,000 lbs/hr.

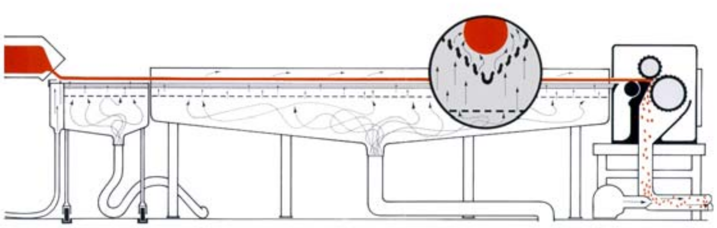

Figure 15. Fluidized Bed Pelletizer.

Drop Pelletizing

DROPPO® is an interesting machine capable of producing uniform spherical droplets made of polymers with viscosities < 500 centipoises, e. g. waxes, resins and low molecular weight polymers. This system is able to pelletize low viscosity melts and liquids that do not form strands. Pelletizing of these materials is done by harmonic vibration applied to the melt in a die head. The melt-flow escaping from the die holes is thus subjected to vibration. Surface tension causes the flow to break into small droplets. The droplets produced become spherical pellets with an extremely narrow pellet size distribution. There is no mechanical cutting involved. Depending on the viscosity and surface tension of the melt, drops with diameters from 0.3 – 4.0 mm ± 10% are generated by varying the frequency and the size of the die holes. DROPPO® spheres offer the ideal pellet shape for exact dosing and homogeneous mixtures, where equal material flow and high bulk density are required.

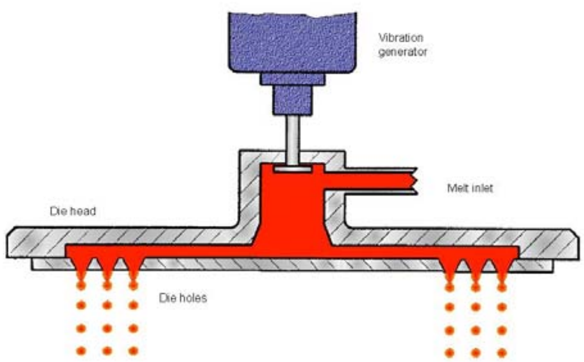

Fig. 16. Basic principle of drop-pelletizing process DROPPO.

Hot Face Pelletizing

With the development of high volume PE and PP plants in the fifties, it quickly became plain that high-strand count lines were problematic, and that if it were possible to cut the polymer the moment it emerged from the die that both handling and throughput would be enhanced. An engineer then working at Union Carbide, Vernon E. (Buck) Dudley, started his own company in 1959, and spent years perfecting such a machine, with the final product schematic looking similar to Figure 17 below.

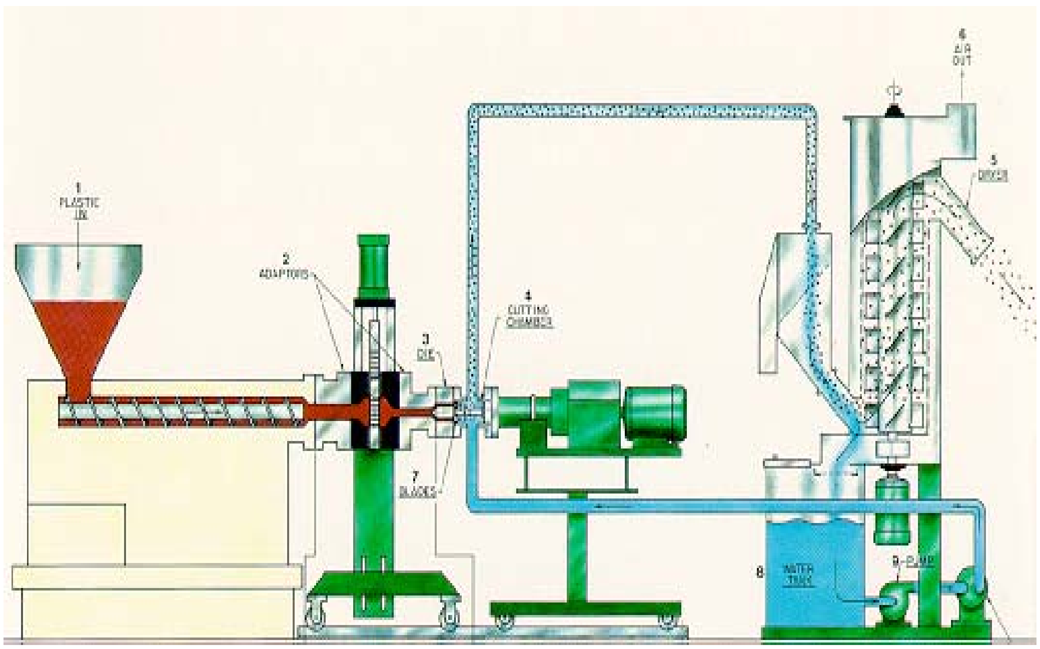

Figure 17. Basic Underwater Hot Face Pelletizing Schematic, from Gala.

Over the years hot-face pelletizing has evolved to meet additional challanges. Orginally designed for olefins, it now finds application in nearly every polymer. Its advantages include fully automated startup, good adaptability to various polymer and additive combinations, lower operational costs, and generally low noise. Briefly, the extruder pumps melt into the head, which directs the flow to a number of strands arranged in a circular pattern. A rotary cutter spins blades against the face of the die while water flows across the blades. The water carries the pellets to the dryer, where a combination of air movement, retained heat in the pellets, and mechanical action of the pellets striking the sides of the screens, dries the surface moisture off the pellets. The crucial insights were that the system had to start simultaneously--cutter, extruder, and water supply. (For an animation of the process go to: **http://www.gala-industries.com/uwg.swf**) The disadvantage of this type of system has always been its tendency to freeze off low viscosity polymers at the die exit, and for glass-filled pellets that wick moisture into their centers resulting in high residual moisture. Recently a number of vendors have announced solutions to these problems.

Figure 18. Die and Insert, Gala System.

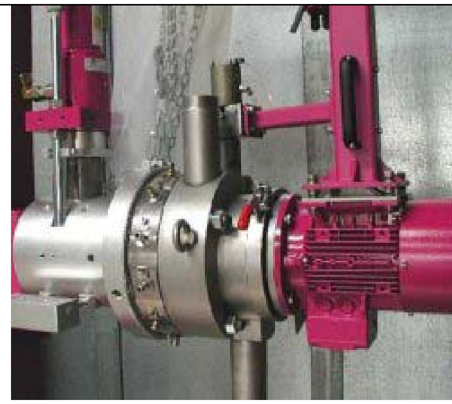

Figure 19. Rieter's Pneumatic Blade Adjustment system.

In the early days hot face systems required that the blades be advanced against the die manually, given the wear caused by friction with both the polymer and the die face. Gala has recently introduced an automated system that both advances the blades and can even signal when they have reached their „wear limit." Rieter has similarly introduced an automated system that advances the blades pneumantically by translating axial movement of the blade motor's rotor. And BKG's system relies on a hydraulic pressure system to push the blades up against the die. Any of these systems will eliminate the need for manual adjustment of the blade pressure.

With regard to the problem of die freeze-off, Gala, BKG and Rieter all have introduced systems that deal with the problem. Essentially, balancing the flow and insulating the die have addressed this problem so that today nylon, PET, and PBT run on all systems. Residual moisture is another problem. Normally a spin dryer can achieve a .5% residual moisture number. Since the dryer works by a combination of impact and residual heat, and since the pellets are coming out of a slurry, it is not possible to remove the moisture from the center of a pellet. For that reason, glass-filled applications generally rely on other technology.

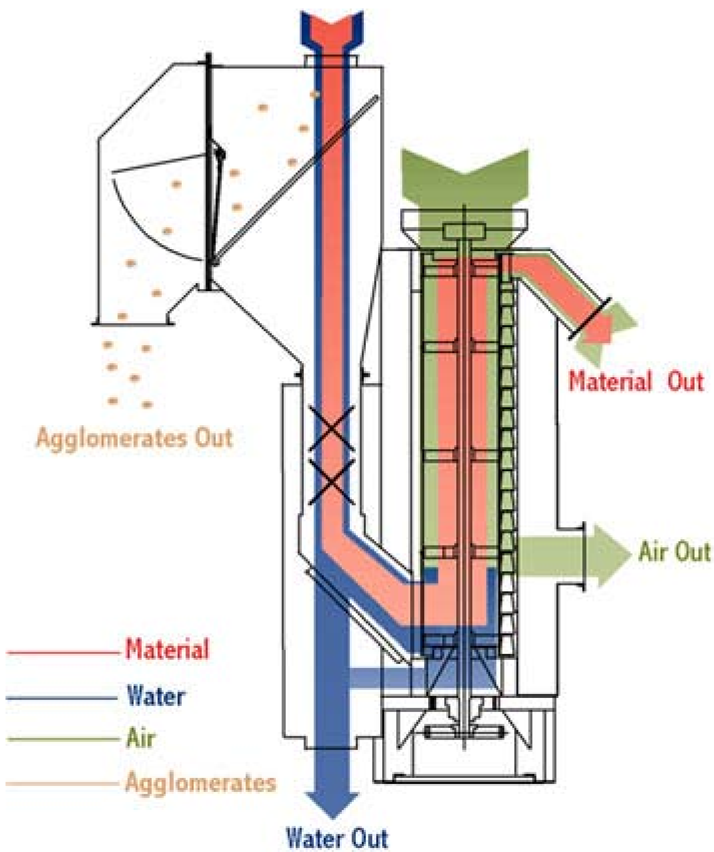

Figure 20. Spin Dryer, from Gala.

Water Ring Pelletizing

The disadvantage of all hot face underwater systems is that they have water against the die face. Should the temperature of the polymer flowing through the die hole drop below its softening point, the hole will freeze off and the flow through the die will become unbalanced. The result is agglomerations or worms rather than pellets. Further, for batch systems in which frequent color changes are necessary, cleanout of the die, tank, and dryer can take time. One solution is to remove the water from the die face, cutting the polymer as it exits the die in air, but then quenching in a ring of falling water. That is the concept behind the Beringer system.

Figure 21. Beringer Water Ring Pelletizer.

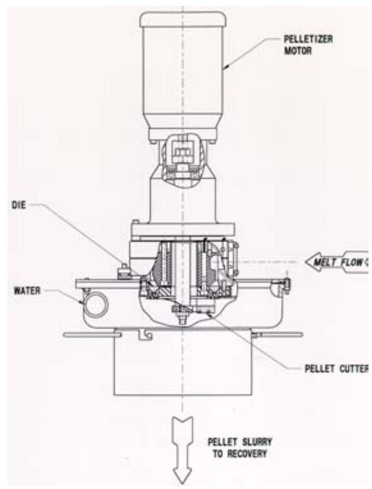

Figure 22. Detail of the Beringer Cutterhead.

The weakness of the system is that the polymer must be of the type that releases easily from metal, so the machine found application in the processing of olefins, mainly. The company has recently addressed a problem that affected the system at throughputs above 2,000 lbs/hr. In the past the pellets would agglomerate in the cooling trough. Now the company has introduced the „S“ series, in which the pellets are submerged in a slurry and then transported to the dryer.

Vortex Pelletizer

A recent entry into the hot face market comes from Conair. Here the concept is to cut the pellets at the face, but instead of arranging the die to face straight down, like Beringer, the face is vertical. The pellets exit the die, are cut, and are trapped in a spinning water vortex spray. This spray cools and seperates the pellets, which then fall into a slurry, are conveyed to a spin dryer, and then discharged.

Figure 23. Vortex Pelletizer from Conair.

New Developments in Machine Rebuilding

Sometimes the most recent development involve the oldest ideas. With the incessant pressure to do more with less, plastics processors everywhere are considering upgrading their machines rather than replacing them. A number of machine vendors now offer such a service. Among the services offered are, replacing PIV drives with motor/inverter combinations, upgrading or replacing the interlocks to improve safety and reliability, upgrading the cutting tools, remanufacturing the cutter housing to original specification, and replacing the electrical components.

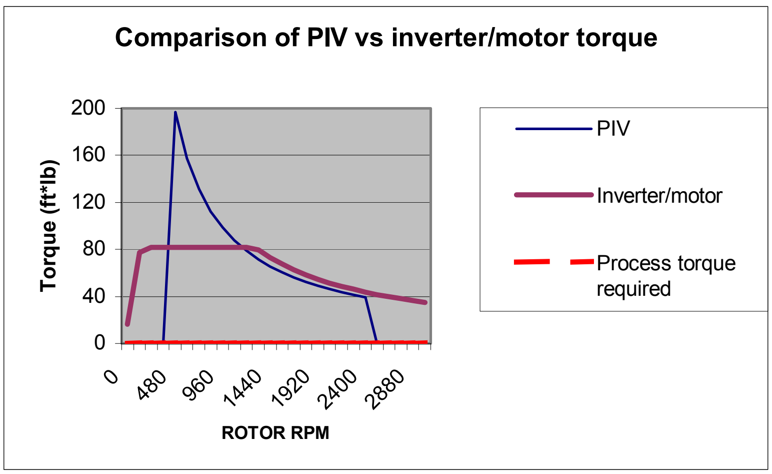

Figure 24. Speed advantage of Inverter/Motor Combinations

Figure 25. PIV inside older pelletizer.

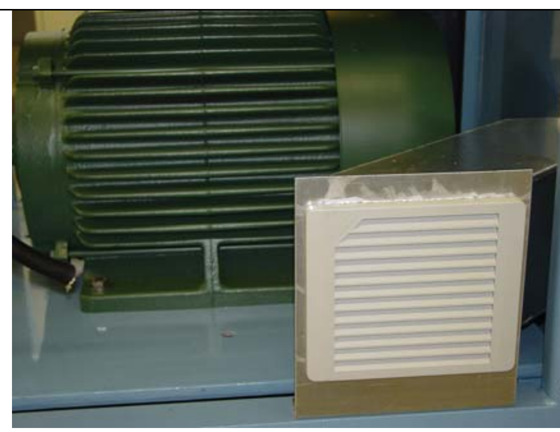

Figure 26. Same machine with motor and vent duct.

The development of electronic technologies also provides some enhancements for the machine. The old PIV or hydraulic drives are now replaced by motor/inverter combinations that offer broader torque ranges and much higher speeds. This makes the machine more versatile—the same machine can run higher throughputs simply because it can pull the strands faster. Further, since some applications require different pellet lengths, the machine can be outfitted with dual drives controlled by a PLC, permitting adjustment of the pellet length on the fly.

Figure 27. Upgraded Interlock sensor.

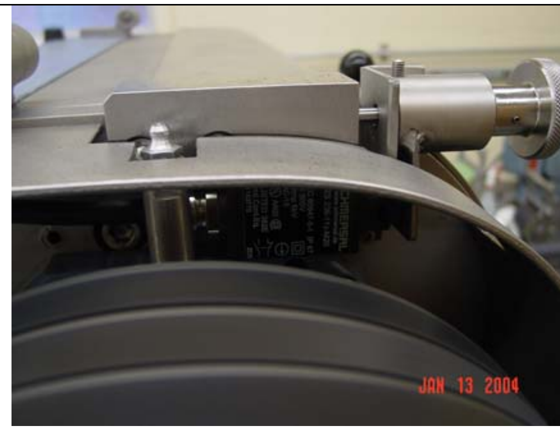

Figure 28. Cutter chamber interlock.

Similarly, the interlocks, which often had failed or were disabled due to malfunction, are prime candidates for replacement. Limit switches, prox sensors, and encoders all have evolved over the past few decades, and today's products are more reliable and robust than those of the past. Moreover, since OSHA requirements for the machines have also changed, it is possible to upgrade in such a manner that the final product meets the existing standards as well as being more reliable.

Figure 29. Strand Inlet, before upgrading.

Figure 30. Strand Inlet, now in OSHA compliance.

Overall, the plastics processor today has many more options than in the past. From the exotic polymers to high-throughput commodity resins, the technology required to fill the niche has divisified, or to quote Darwin, *„whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved."*