THE PLASTIC
TECHNOLOGY
MAGAZINE

insideextrusion

Extrusion Planet:
tips and tricks to discover

UNDERSTANDING EXTRUSION
Increasing productivity and turning it into a competitive advantage.

LESS POWER CONSUMPTION
Energy is the largest indirect cost. Companies need broad changes across their operations.

BUSINESS AND SOCIETY
The lean and green factory isn't a simulation. It is a real production environment.

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BAUSANO OPENS UP TO NEW EXTRUSION TECHNOLOGIES FOR PIPES

Bausano instructs **Massimiliano Fenili,** as Technical Manager in charge of supervising the design of systems for the various application areas: granules, pipes, profiles, WPC, medical sector and for recycling. The appointment of Fenili falls within a broader project in which Bausano is committed to strengthen its own team. The Manager's high expertise in pipe extrusion technology is aligned with the corporate strategy of being one of the main players in the market for such solutions. We shall examine the trends in the sector directly with the expert.

What are the application areas in which the use of plastic pipes is increasingly widespread?

"In general, we can say that demand is moving towards ***more efficient*** *solutions. This is translated into an increase in the demand for* ***polyethylene (PE)*** *pipes, a material that guarantees important benefits in terms of reducing installation times and costs, even up to 50%, thanks to its flexibility, ease of installation and possibility of trenchless installation or without a sand bed. Specifically,* ***PE100 RC*** *is frequently used thanks to its higher mechanical performance, resistance to external abrasions, reduction of the propagation of cracks and resistance to high pressures. To mention two areas in which demand has grown, we may certainly consider the* ***infrastructure sector****, for gas pipes, pressurised and non-pressurised water, and the* ***telecommunications*** *sector. The first one searches, most of all, for multilayer pipes capable of carrying out various functions, from resistance to high pressures up to reducing installation costs. On the other hand, in the telecommunications sector the diffusion of optical fibre at a domestic level encouraged the study of new types of piping and installation, from the single microduct to the bundle, fender and round structures.*

In addition to the aforementioned polyethylene, ***multilayer polypropylene (PP) pipes*** *are certainly expanding, which combine maximum flexibility and resistance to several climatic conditions capable of carrying out various functions: from the reduction of noise for the drain pipes, to the ability to resist to very low temperatures. Furthermore, the combination of PVC and polypropylene is often chosen as an alternative aimed at keeping costs down. Alongside PE and PP, there are also* ***PEX, PERT*** *and* ***PB*** *materials, used in the healthcare sector, especially in the multilayer versions with oxygen barrier. While C-PVC, specifically, is already widespread in India and has a very large market in the United States. Finally,* ***reinforced thermoplastic pipes*** *(RTP), ideal for sectors such as Oil & Gas, are products in which strong interest is growing".*

In light of the above, which technological innovations will the expansion of the Bausano tube division focus on?

"First of all, the R&D Area will be engaged in expanding the range of extrusion lines for pipes with a ***diameter*** *of up to* ***1200 mm.*** *The main purpose is that of supporting customers in achieving their own goals, by defining the correct setup of machines with the consequent collection of data and the related definition of production* ***KPI****. Within this context, digitisation and Industry 4.0 play an essential role. The development of the* ***Orquestra software****, a centralised control system which allows continuous and real-time monitoring of performance, even in terms of predictive maintenance, by guaranteeing increasingly high levels of efficiency is an example of how Bausano is responding to these new needs. These levels, in turn, are aligned in terms of sustainability which, in its several forms, plays an increasingly central role, of which Bausano is already a precursor. An example is the* ***Smart Energy System****, the induction cylinder heating system, thanks to which it is possible to limit the wear of the machinery and to achieve energy savings of 35%. Furthermore, the company invests on the reduction of production waste: by equipping its extruders with advanced technologies and, on the other hand, by developing extrusion lines capable of regenerating in -house industrial residues or post-consumer household waste".*

What are Bausano's long-term goals?

"The team I join is heterogeneous, dynamic and characterised by consolidated experiences and transversal skills. An essential aspect in order to ensure strong integration between the various departments and encourage product and process innovation. At the same time, this allows us to offer customers a very high level ***pre and post sales consultancy****. Finally, the Team will be in charge of coordinating R&D activities, in compliance with Bausano's strategic lines of development and growth in new markets, such as the United States".*

Contents

SCREW WEAR: CAUSES, CONSEQUENCES AND SOLUTIONS

Mechanical components and most engineering systems in which there are bodies moving relative to each other can incur dysfunction and deterioration in performance due to the wear and tear that occurs in these components. Extruders are used in a wide range of process industries and high reliability is essential if cost effective manufacturing is to be maintained. Critical parts of the extruder are the barrel and the screw that must withstand many different wear and corrosion environments depending on the end user.

Causes

In the extruder, the relative moving parts are the screw and the barrel, and there is also a fluid flowing through the channels that can cause additional wear. There are many factors that can cause the screw and barrel to wear:

- cold start of the screw
- wrong material processing (e.g. corrosive polymers for a screw not suitable for corrosive polymers)
- uneven heating of the barrel
- improper screw and barrel alignment
- non-straightness of the screw
- abrasive additives in the polymer formula
- incorrect screw and/or barrel material
- corrosion due to polymer or additive degradation

All of these factors relate to three main wear phenomena: **abrasive, corrosive and adhesive**.

Abrasive wear is caused by the hard particles (e.g. glass fiber, calcium carbonate, flame retardants) with which the polymers are added. The sliding of the polymer in the screw channel at high pressures and temperatures causes abrasive phenomena by the hard particles which creep and impact the metal surfaces of the screw and barrel. The amount of abrasive wear also depends on the hardness of the particles, their shape and size. This type of wear can be reduced by surface hardening of the screw and barrel (e.g. nitriding, chrome plating).

Corrosive wear is due to corrosive additives and degraded polymer particles chemically attacking extruder components. The largest portion of corrosive wear usually occurs in the metering zone where temperatures are higher and the material remains for longer increasing the possibility of product degradation. The effects of this wear can be decreased by using the same surface treatments that decrease abrasive wear.

Adhesive wear can be caused by the metal-to-metal contact between the barrel and the screw, which, while rotating, can cause a momentary contact between the thread crest and the surface of the barrel from which a sort of small weld is originated, immediately removed by the rotation of the screw. This wear phenomenon can be effectively reduced or even eliminated by a correct alignment of the screw in the barrel and by a straightness of the screw and barrel as much as possible.

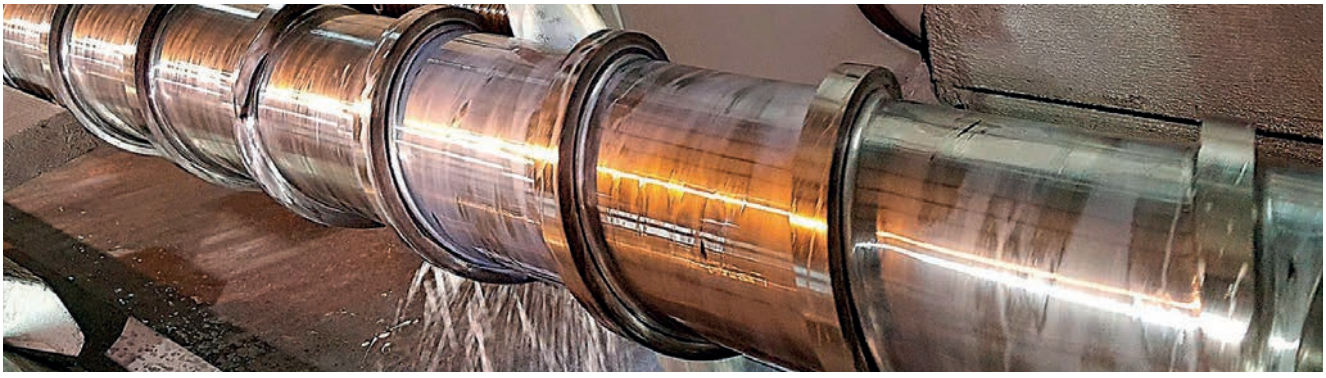
The first evidence of wear

The first consequence of wear that can be observed is the reduction of the maximum flow rate that can be processed by the extruder. The screw, which is designed to rotate within the barrel, has a thread diameter slightly smaller than the barrel diameter to allow free rotation of the screw. By design, the gap between the crest of the thread and the surface of the barrel is small and is filled with molten polymer that acts as a lubricant. Non-abrasive polymers and proper alignment of the screw within the barrel can ensure continuous operation of the extruder for up to ten years with almost no wear. When abrasive polymers are processed, the alignment is not correct or other of the above mentioned wear factors occur then the wear phenomena have consequences especially on the screw thread, mostly wearing out the thread crest and thus increasing the gap between thread and cylinder surface. As the gap increases, extruder performance decreases, i.e. polymer temperatures at the extruder outlet increase, process instabilities increase and flow rates decrease.

"DEGRADATION LEADS TO AN IRREVERSIBLE LOSS OF THE MECHANICAL AND OPTICAL PROPERTIES OF THE EXTRUDED POLYMER"

The first signs of progressing wear are manifested as the flow rate of material processed by the extruder decreases. When high wear is reached, there is excessive material leakage above the thread and therefore the total output flow rate of the extruder is reduced. In the case of a worn screw, it is necessary to increase the speed of rotation to maintain the original design flow rate and discharge pressure. The maximum acceptable amount of wear is that which still makes the extrusion process economically viable. Wear can occur in all parts of the screw, but it usually tends to be greatest where the pressures involved are greatest and thus in the transition and dosing zones.

Another consequences of screw thread wear is an increase in polymer temperatures. The increase in temperature first breaks the weak bonds between the macromolecules, but then also breaks the covalent bonds leading to the chemical degradation of the polymer. Thermal degradation, which occurs above melting temperature, can occur either because temperatures are reached too high or because the polymer is kept at high temperatures for too long. Degradation leads to an irreversible loss of the mechanical and optical properties of the extruded polymer. The rupture of covalent bonds leads to the formation of volatile species because small molecules are formed from the rupture of macromolecules that are in a gaseous state. Another consequence of thermal degradation is the yellowing of the molten polymer and therefore of the finished product, and in the worst cases it is possible that carbon residues are also formed.



Tailor made solutions

Bausano screws are designed specifically for the production needs of each customer and for this reason they are perfectly adapted to the characteristics of the polymer to be processed. In particular Bausano screws are coated with an hard metal (e.g stellite) that prevents screw wear. Then, to the barrel is applied a bimetallic coating. In this way, the life of the screw is significantly increased, eliminating all problems related to the partial compatibility between the screw and the material to be processed.

U-PVC PROFILE EXTRUSION DIES

Use of **U-PVC** in engineering applications is well established.
Its advantages in terms of **replacement** of metal and wood, light weight, ceaseless nature, weld-ability, aesthetics, energy conservation and low cost makes it very popular. Though U-PVC pipe is considered as a round and simplest form of profile, the die **design aspects** are quite intricate.

Profile dies design aspects:

Being **asymmetrical**, dies **need to be balanced** to have uniform extrudate flow perpendicular to the die. This would also eliminate the differential stresses frozen in the profile during cooling.

Melt pressure within the die varies inversely with the cube of die opening. To facilitate die balancing, dies usually comprise the number of **rectangular plates**. This also facilitates machining, chrome plating and gradual compression for gentle flow.

Alignment of plates within hollow sections is very important. This would avoid stagnation of degradable PVC compounds and provide a streamline flow.
This die balancing also takes care of different die swells at different wall thicknesses of intricate profiles.
Alignment of plates outside too is important for firm contact of die heaters for effective and uniform heating.
To fine control flow in intricate dies, often four thermocouples are provided on four sides.
Heating system with firmly held thermocouples capable of controlling temperature within +/- 1°C is essential.

In case of profile dies, **changing die land length** to balance the die is preferable because the effect is linear. Die design of intricate profile is not simple. Thickness requirements in different parts of the product may be different. This complicates die designing.
During trial, if product dimensions are not correct, plates **can be successively removed** and extrudates can be inspected to locate corrections required.

Practical considerations:

Profiles having a thickness of say 1+ 0.1 mm, it is observed that after running the die during production, the thickness of the profile gradually increases due to wear & tear.

This results in two effects:

- Weight of the product per meter increases
- The line speed decreases.

Both these factors result in an increase in cost/m of the profile. Besides, over a period of time, due to wear and tear of the screw/barrel, the output also decreases.
It is therefore advisable to ask the die manufacturer **to provide** die to produce minimum wall thickness as per the tolerance required. If slightly more thickness is required, it can be achieved through use of **additives** including appropriate processing aid.

It is also advisable to ask for **additional front plates** in the die.

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CUSTOMISED EXTRUSION LINES COMPLETELY MADE IN ITALY

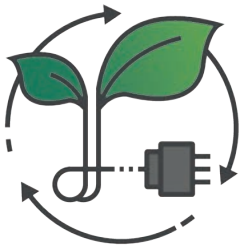
PIPES

PROFILES

COMPOUNDS

MEDICAL PRODUCT

POST INDUSTRIAL SCRAPS RE-GRANULATION



Less power consumption extrusion lines
100% Made in Italy

✓ Patented extruder since 1946

Extrusion lines stand out not only for their quality, great solidity and extreme reliability, but also for the great energy saving.

Greater **durability, exceptional performance and great energy savings** thanks to the revolutionary **transmission system** with two intermeshing and **counter-rotating screws**, **patented** by Bausano.
Up to 35% less power consumption thanks to the innovative **Induction Heating System** and realtime energy analysis of the entire system with the **Digital Extruder Control 4.0 system**.
The key to success of our products is customization: from electric or electronic to mechanical components, from touch-screen monitors to appearance of elements and lines, everything is shaped around the special needs of the customer. **Each extruder is unique**, even different from the others belonging to the same series. What never changes is the ability to optimize production, cutting down costs and passing any tests with **exceptional results**.

Model	Installed Powers	Motor Consumption
MD 170/28	Ceramic resistors 192 kW	I.E.2 low-efficiency motors
MD 170/28 Nextmover	**Smart Energy System 124 kW**	**High-efficiency motors**
DIFFERENCE >>	**- 68 kW**	**Energy Saving - Motors - 5%***

*Motors running at 50 HZ, 380V

THE BASIC PRINCIPLES OF PIPES EXTRUSION

BAUSANO ANNOUNCES THE INAUGURATION OF THE NEW DESIGN DEPARTMENT FOR PIPE EXTRUSION LINES

This is a sector which has much relevance. And pipes are without doubt indispensable components in many of the infrastructures that surround us. The **pipe extrusion** is in fact the topic of this article.

A pipe extrusion line consists of different parts. An extruder converts raw plastic material into a continuous tubular melt by extrusion through an annular die.

The molten pipe then proceeds through a sizing or calibration bench (which adjust its dimensions) to a cooling tank. After being cooled, the pipe passes via an haul-off to the cutting machine, for cutting it into final lengths, or coiling.

Single or Twin screw extruders are used for pipe manufacturing.

Extrusion Process

The profile or tube are pulled by an haul-off unit so that the line it is always in motion. Finally, depending on the flexibility of the product, a **cutting or winding unit prepares the product for distribution**.
In the head there is much of the secret of a good product. It can be a model with porta mandril, with spiral, or with spider for PVC.
Each of these designs provides a different flow.

The calibration bench, if we talk about pipelines, has the function of providing to the pipe a specific diameter and the circular shape that the product requires. You can do the calibration using vacuum or pressure.

For smooth pipes the most common system is the vacuum calibration. The vacuum caused on the outside of the tube allow the polymer, yet malleable thanks to the high temperature, stay in contact with the metal pipe head which has an inside diameter equal to the outer diameter specific for the product.

In the case of **corrugated pipes**, vacuum calibration use the same principles as for the smooth tube. In the calibration of the corrugated pipe, the pressurized air penetrates through the channels practiced in the head and they inject the material in the still hot extruded tube. The difference in pressure caused, shapes the surface of the plastic pipe pushing it against the system, providing the product the required corrugation.

And then, we got to the cooling tank that eliminates the residual heat of the pipe that remains at the exit of the calibration tank. The **importance of cooling**, lies in the stability that acquires the plastic to not deform when passing through the haul off unit, where the tube is subject to pressures that could produce alterations in the circular shape required.

Pipe Cooling System

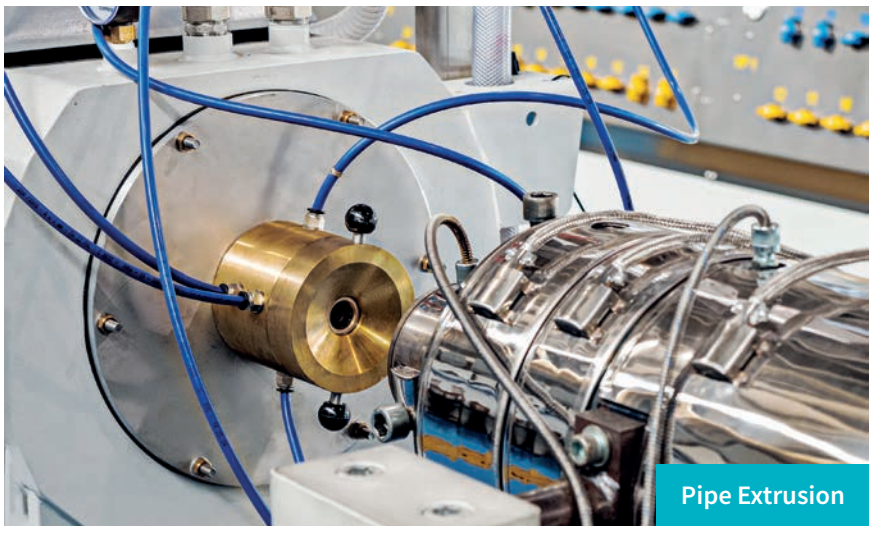
By spray or immersion baths you can cool it down. The first system is used for pipes with large diameter, where production speeds are low and the spray can achieve effective cooling. In the immersion the tube passes through a water-filled container in constant cooling.

Once cooled, it pass to the **Haul off unit**, which generates all the strength which, to put it in some way, **pulls the profile or tube in order to extract it from the extrusion line**.

The **last step is the cutting unit**, which also depends on much of the type of product that is manufactured. If we talk about pipe and the pipe is coiled, the cut is logically a little relevant work. But many tubes should be cut out of the extruder in equal lengths, either by lack of flexibility to be coiled or other considerations. When choosing the cutting system must be taken into account the diameter and wall thickness, the raw material used, the shape, quality and the length of the cut.

Cutting by guillotine is effective, but can produce slight deformations by the impact of the blade. With saw cuts the small dentures that cut the pipe cause small shavings that sometimes remain attached to the tube.

To avoid the formation of these residues, it is used a mechanisms where the blades are inserted in the wall of the tube and spin at high speed, producing only a strip of shavings but preventing deformations.



Pipe Extrusion

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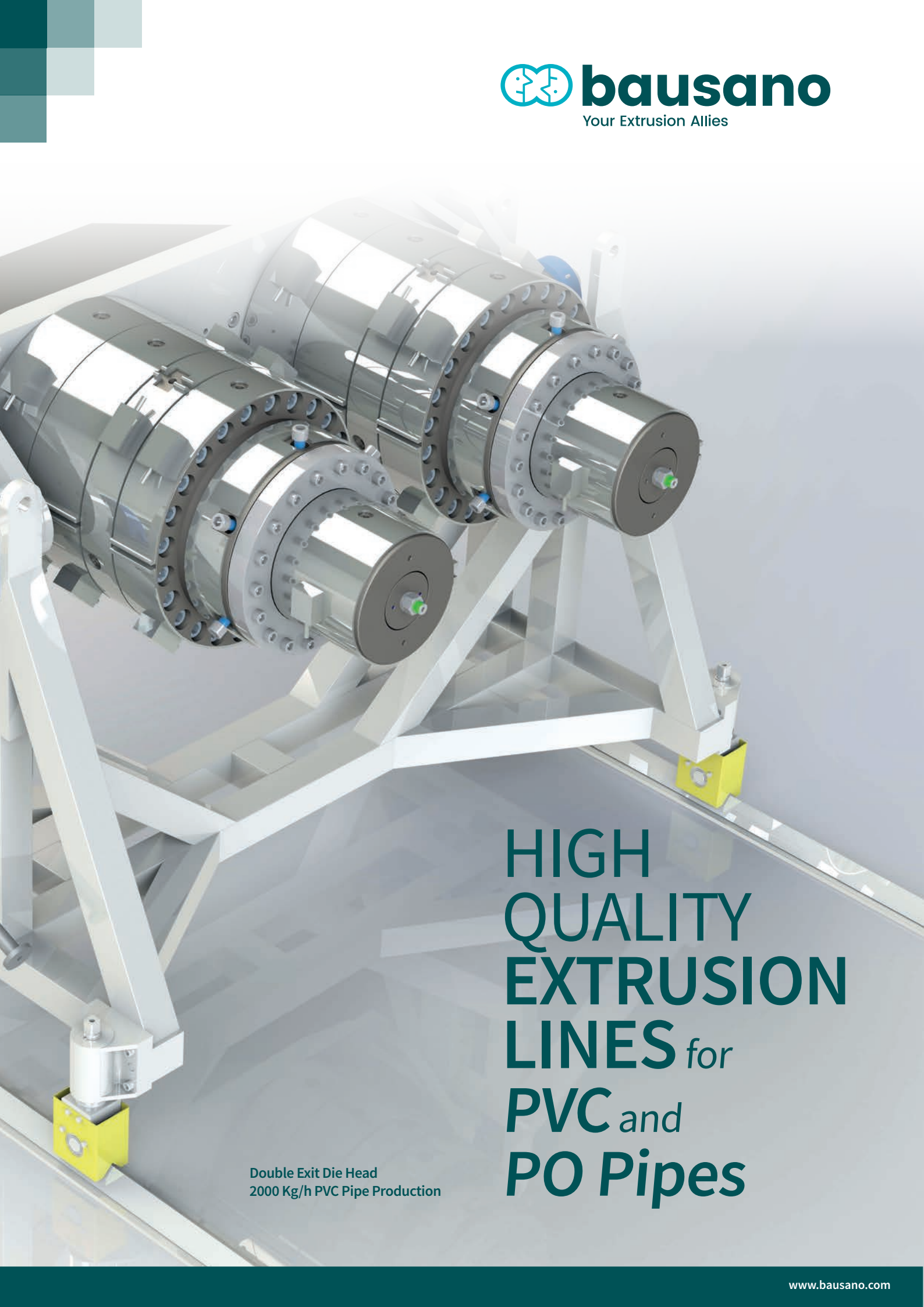


HIGH QUALITY **EXTRUSION LINES** *for* ***PVC*** *and* ***PO Pipes***

Double Exit Die Head
2000 Kg/h PVC Pipe Production

HIGHER DIAMETER HDPE PIPES AND COOLING PROBLEMS

The production of larger pipes diameter and higher thickness is still considered biggest challenge in the industry. **Maintaining dimensions** within specifications is problematic for the extrusion of **large diameter thick-wall HDPE pipes** (> 75 mm wall) due to sag caused by insufficient resin melt strength.

The diameter of HDPE pipe increases during extrusion and it causes a **thickness increase**, pipe doesn't effectively cool from inside and within the core, and the linear speed decreases.

Large diameter pipes may have various segments of **different crystallinity, thickness**, and **moisture content**. In most HDPE extrusion processes 60% to 80% of the crystallization takes place during the cooling phase of processing. However, crystallization continues until a stable crystal structure is achieved.

In the manufacturing of large diameter pipes, particularly from multimodal polymer material, one challenge is maintaining uniform dimensions all around the pipe.
This is due to gravity flow of the polymer melt, causing it to flow from the upper part of the pipe to the lower part, it's called "sagging".
This can cause serious non-uniformity in pipe wall thickness.
This sagging problem is particularly pronounced in thick-walled large diameter pipes with a wall thickness of at least 100mm.
Sagging can cause producers more costs by not meeting wall thickness required and wasting more material. So a solution has to be found. There are some ways to control the sagging effect.

We have to ways to compensate sagging:

- By **offsetting the die gap**, but this takes time and always leads to the use of additional material
- By **using low sag HDPE material composition** and optimization of the cooling process.

The conventional way to reduce sag is by **manually adjusting the die eccentricity**, until an acceptable wall thickness profile is achieved.

To **minimize efforts** and compensate the effect of sag, the die gap is adjusted before starting the extrusion in such a manner that the die gap is more at the top and less at the bottom of the die.

We can use ultrasonic on line **thickness measuring instruments**, with four locations at 90° to each other and give a display of thickness variation on the screen. Alternatively, portable equipment may be used to measure on line thickness at various places of the pipe.
Once we have knowledge of thickness variation, **we can** fine tune it by **altering temperature of segmented heater** appropriately to control thickness and save wastage as well as improve quality.

Due to the high wall thickness and the slow cooling process governed by the thermal conductivity of PE, it is of utmost importance that the **HDPE in molten state** possesses sufficient melt strength to **prevent the material from sagging** to the bottom of the pipe.

The use of **Hexene**, an organic compound, developed for very large diameter pipes is known to provide better slow crack growth resistance and resistance against rapid crack propagation, and a superior melt strength.

The **molecular weight distribution** has been adjusted to increase the viscosity at low shear rates, which reduces the sag, while allowing the same material to be used for smaller diameter pipes.

The pipe is extruded through a ring formed die and cooled on both inner and outer surfaces. This double-sided cooling is said to eliminate the deformation of the pipe due to gravity-induced flow of the melt emerging from the die.

In conclusion, improved extra low sag material is the ideal choice for thick-walled and large diameter pipes. This material can save pipe convertors while being also an enabler for pipe designers and producers.

USE OF CORRUGATED HDPE PRODUCTS

Corrugated HDPE Pipe Characteristics

High-density polyethylene (HDPE) is a versatile material and has some ideal characteristics for use in underground structures. HDPE pipe is relatively lightweight allowing for easier and less costly transportation and installation costs. It is not brittle and therefore not susceptible to cracking during pipe handling and installation activities.

Once formed into a pipe, HDPE has a smooth surface, which is resistant to abrasion, corrosion and chemical scouring. The smooth surface provides excellent pipeline flow characteristics. HDPE pipe is structurally strong and has the ability to support large loads. HDPE has the ability to relax under stress. This characteristic provides advantages for underground structures and also helps define limitations of use. As HDPE pipe is loaded, the pipe relaxes immediately, and over time, allows the load to be transferred to the adjacent soil. This characteristic allows the pipe to off-load points of local stress. Stress relaxation may result in slight pipe reformation over time to accommodate inplace loading conditions. Such re-formations are believed to cause long-term structural stability.

Corrugated HDPE is an excellent choice for gravity flow or low-head pipeline situations. The structural stability of corrugated HDPE pipe is produced by three pipe designs. According to AASHTO M294, they are defined as:

- **Type C** – This pipe shall have a full circular cross section, with an annular corrugated surface both inside and outside
- **Type S** – This pipe is a full circular dual-wall cross section, with an outer corrugated pipe wall and a smooth inner liner
- **Type D** – This pipe is a circular cross section consisting of an essentially smooth inner wall joined to an essentially smooth outer wall with annular or spiral connecting elements

Type C HDPE Pipe with Interior and Exterior Corrugations

Advantages of Corrugated pipes

Corrugated Pipes made from Polyethylene and Polypropylene raw materials and have a high resistance to corrosion. They have a guaranteed life of 50 years and can be used for 100 years. Since plastics are smooth hydraulic, they high resistance to flow and the fluid flows with a higher filling rate. This advantage to reduces the project costs by selecting a lower diameter group in the project.

Technical applications:

Flexible single wall, double wall and multi-layer corrugated pipe for the protection of cables in automotive and machine construction. Applications also in healthcare, telecommunication and household. › Diameters: from 3 mm i.d. to 200 mm o.d.

- Cable protection: Flexible single wall, double wall and multi-layer corrugated pipe for cable protection, inhouse building, road construction and long-distance circuits. › Diameters: from 10 mm i.d. to 250 mm o.d.
- Drainage: Single, double or triple wall pipe for civil engineering, land and road drainage. › Diameters: from 50 mm o.d. to 1200 mm o.d.
- Sewage and storm water: Double and triple wall pipe for waste water and storm water disposal. › Diameters: from 100 mm i.d. to 2400 mm o.d.

FREQUENTLY ASKED QUESTIONS: HDPE PIPE FOR WATER

COMMONLY ASKED QUESTIONS ABOUT USE OF HDPE

What is the life expectancy of HDPE pipe in water applications?

Many installations of HDPE pipe in water applications are already reaching 50 years of successful service. The polyethylene pipe industry estimates a service life for HDPE pipe to conservatively be 50-100 years. This relates to savings in replacement costs for generations to come.

Will HDPE pipe float in water?

Yes, HDPE pipe, due to its density being slightly less than water, will float even when full of water. When it is desired to ensure flotation of the line, various forms of collars, saddles, and strap-on flotation devices are available. For underwater anchored pipeline installations, it is important to specify the proper weights and spacing of the weights. Screw-anchors are a practical alternative. Whenever possible, an underwater pipeline should be installed in a trench with protective crushed rock cover.

How does the impact strength of HDPE compare with other pipes?

HDPE is a ductile material and has exceptional impact strength. HDPE's superior impact strength provides a piping system that is near impervious to impact damage and to damage from improper tapping. In the real world, engineers understand that pipes must be tough and resist impact and handling damage. HDPE pipes are field tested and proven to be impact tough.

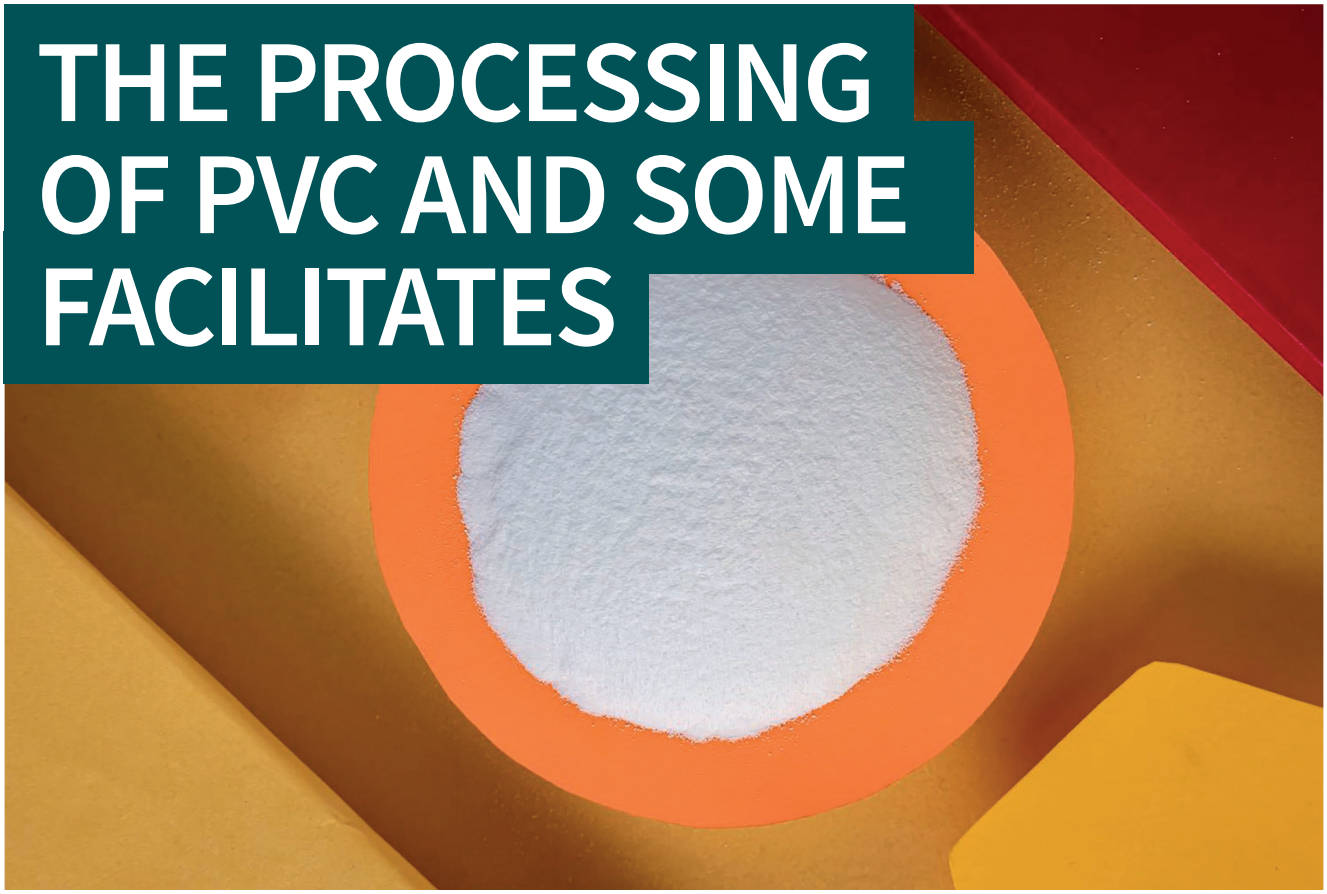
How is HDPE pipe connected and joined to PVC pipe?

Methods of joining HDPE pipe to PVC pipe vary with the size and style of PVC. Common methods include slip-joint anchor fittings, gasketed joint adapters, and flange connections. HDPE to PVC transition fittings are also available from certain fittings manufacturers; also, refer to PPI TN-36, General Guidelines for Connecting HDPE Potable Water Pressure Pipes to DI and PVC Piping Systems, for additional information.

How can HDPE pipe be connected to other pipe products such as ductile iron pipe or valves?

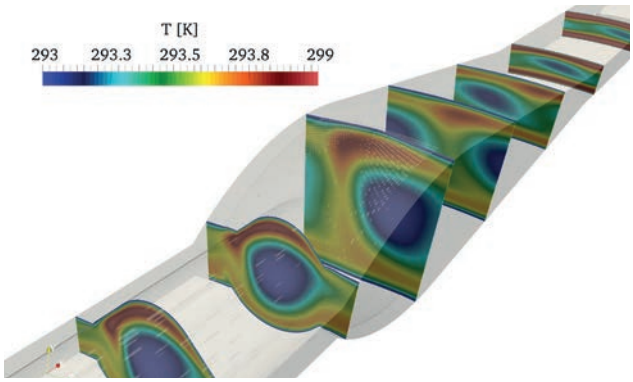
For pressure applications, HDPE transition fittings, HDPE mechanical-joint adapters, gasketjoint adaptors, HDPE flanges, and standard metal couplings with internal stiffeners are recommended. The most common method is to use an HDPE MJ (mechanical joint) adapter to connect the HDPE pipe end in a DI MJ bell using the bolt and gland kit supplied by the HDPE MJ manufacturer. DIPS sized HDPE pipe may be inserted directly into an MJ bell with a restraint ring and insert stiffener for the HDPE pipe. When joining HDPE pipe to a DI pipeline either the DI joints must be restrained or the transition connection must be anchored.

THE PROCESSING OF PVC AND SOME FACILITATES



PVC is one such **polymer** that cannot be processed without compounding.Although standardizing formulation and carrying out mixing, it is still observed that we do not get the repeatability in terms of processing as well as properties of PVC products.This happens because the **quality of ingredients** of the compound, including PVC **is variable**. Most of the PVC processors rely on supplier's test reports.

Organizations try to buy **additives** at slightly cheaper rates to save money, even if most PVC processors use the same standard formulation, each time there is a change in additive, the **formulation needs to be adjusted**.



This leads to:

- More setting time,
- More rework,
- Inconsistency in properties of the product, and
- Increase in production cost.

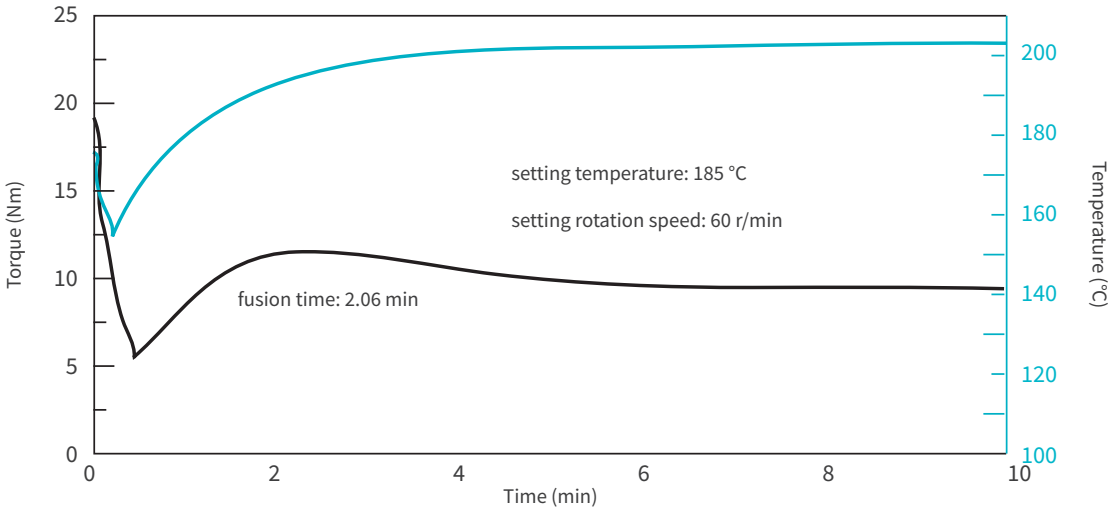
It is necessary to understand that there is not a standard formulation, so the process cannot be standardized and the process becomes operator dependent. This defines the requirements of the quality management system.

In order to make the process work as per the standard control plan, without major changes by the operator, we need to modify the compound at laboratory level in such a manner that the process works within the set tolerance limits of the control plan parameters.

How is it possible?

There are some instruments which enable it to avoid losses in terms of generating, handling and processing more rework, and Inconsistent quality. The best technical instrument for this type of test is the **torque rheometer**, able to generate a **graph** (as you can see from the image) that represents the parameters you want to achieve. By continuing to change the mixture of additives to the raw material you will get graphs always different, and you will be able to find the **best combination** to achieve the desired result.

Rheology deals with the **viscosity** and **elasticity** of a polymer at processing temperature. These data are then processed and compared on a graph generated by the system. A **comparison** can be made between the reference graph and the graph for the newly formulated compound, using a new additive or same additive from a different supplier, tested at same conditions, for the same quantity of compound and by the same operator.

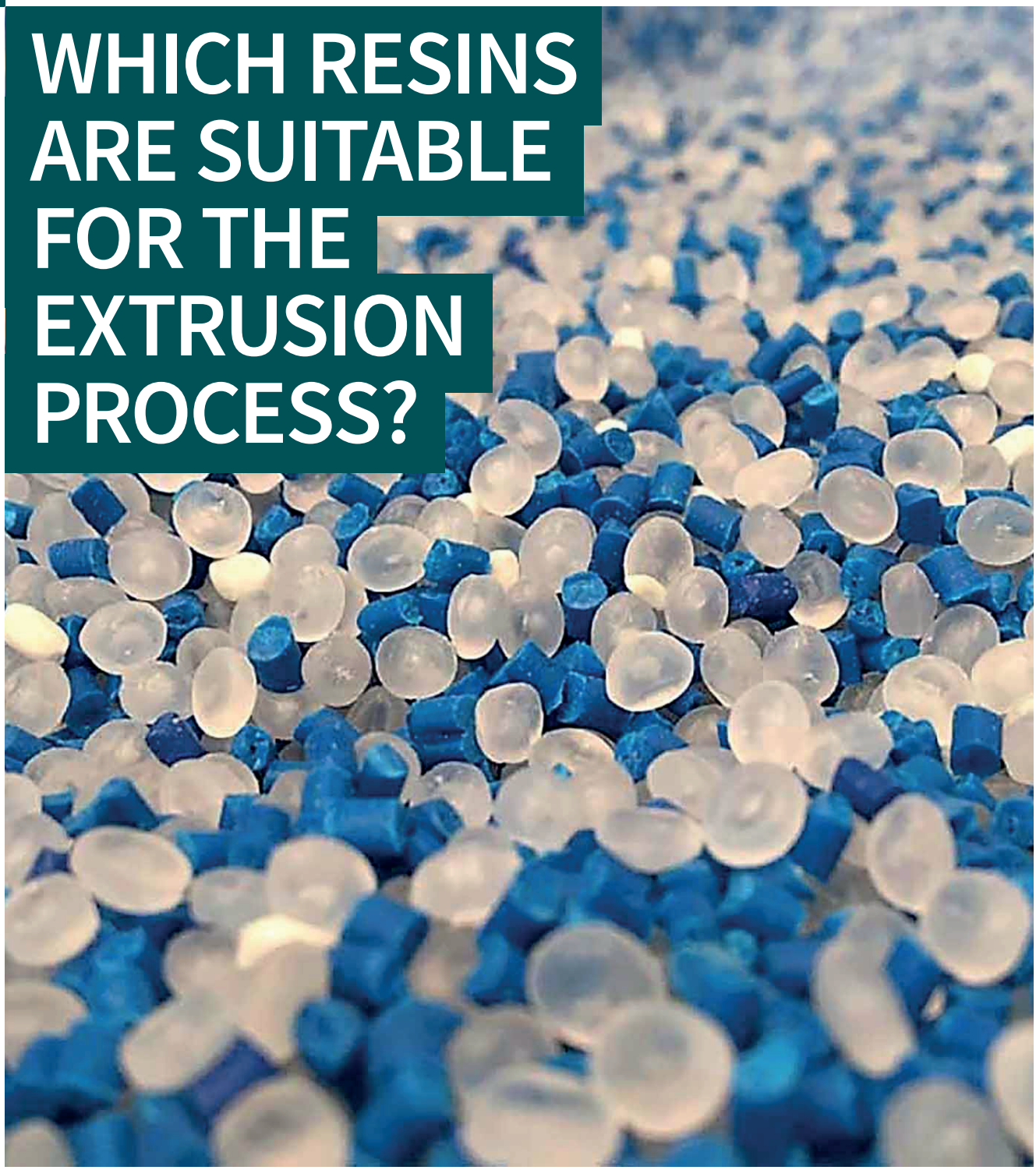


The comparison will guide us to decide whether to add or reduce thermal stabilizer or lubricant or both and its level. Once this is done, the modified compound would run on the processing equipment in such a manner that the operator would not detect the change of recipe and it will run as a compound running earlier. Operator has only to **fine** tune within the tolerance limits of processing parameters.

2023 OPENING AN ADDITIONAL TEST ROOM

In this technological hub, equipped with state-of-the-art systems, the Bausano team will be able to perform all kinds of tests, not only for its partner companies but also for potential customers who would like to get a first-hand look at the quality of Bausano extruders.

WHICH RESINS ARE SUITABLE FOR THE EXTRUSION PROCESS?



After you've determined which material properties your part requires, you can begin your search for a resin.

Not all resins are suitable for the extrusion process, not all are extruders suitable for your ideal resin.

As such, we strongly encourage you to collaborate with a raw material supplier and/or an experienced extruder for this step. They can make recommendations based on your design and part requirements, reducing risk of costly tooling changes and part failure in the future.

Understanding Extrusion

The most widely used resins are included in the table below along with a corresponding rating for some of their critical material properties. These resins can also be enhanced with additives to better meet your required material properties.

MATERIAL TYPE	RIGIDITY	HEAT STABILITY	CHEMICAL RESISTANCE	IMPACT STRENGTH	RELATIVE COST
Polypropylene (PP)	Excellent	Excellent	Excellent	Excellent	Low
Low Density Polyethylene (LDPE)	Poor	Poor	Good	Excellent	Low
Medium Density Polyethylene (MDPE)	Good	Poor	Good	Excellent	Low
High Density Polyethylene (HDPE)	Excellent	Poor	Good	Excellent	Low
Thermoplastics (TPR, TPV, TPO, TPE)	Varies	Excellent	Excellent	Excellent	High
Acrylonitrile Butadiene Styrene (ABS)	Excellent	Poor	Poor	Excellent	Medium
Polyvinyl Chloride (PVC)	Varies	Poor	Poor	Excellent	Medium
Polycarbonate (PC)	Excellent	Excellent	Fair	Excellent	High
Nylon (PA)	Excellent	Excellent	Excellent	Excellent	High

Again, we strongly recommend that you consult with a material supplier or extruder to make the best selection for your unique part design and performance requirements.

Combining Materials

Bausano Extrusion Lines have the ability to extrude two or more materials through a process called co-extrusion in which two materials merge together into a single profile before cooling. Each material used maintains its desired characteristics (such as stiffness, impermeability, or environmentalresistance). The result is a specific shape of constant cross section to be used as used as specific products, assembly components, or as raw stock material for further processing.

Dual density co-extrusion:
To achieve a dual- hardness density co-extrusion with both rigid and flexible properties, two machines are used to feed two different materials through the same die. Co-extrusion allows for rigid profiles to have flexible lips or flaps or for two rigid profiles to be joined by a flexible hinge.

Two-color co-extrusion: It is possible to combine two different colors in the same extrusion or to produce a twocolor extrusion with a dominant color and a stripe in a second color.

In conclusion, the key to a successful extrusion is to create harmony between profile design, material and Extrusion Line features.

TESTED MATERIALS, QUALITY IMPROVED

Testing is determination of one or more characteristics of a product, according to procedure.

An authentic test result is the input for the next process and for:

- Evaluate improvement in quality of product from new raw materials and additives
- Ensure that the manufacturing process is controlled within the “processing window”
- Ensure that the product has characteristics as per customer requirement.
- Ensure that the product meets national or international standards
- Confirm design concept
- Compare product quality with competitor’s quality
- Verify how the product will perform under severe conditions.
- Carry out research and development
- Once the purpose is decided, it is necessary to have an “inspection plan” in terms of frequency of drawing samples, number of samples to be drawn, on line sample drawing procedure, number of samples to be tested, conditioning to be done, standard to be followed for test method, requirements of the test results, and reporting test results.

Conditioning of drawn samples:

Unlike metals, properties of **plastics are influenced by temperature**. Conditioning of samples is done to obtain reproducible results irrespective of previous history of exposure. This is done by following an applicable conditioning standard.

It is also necessary to report **conditioning parameters** as well as test methods followed in the test report. It is imperative that the test equipment are calibrated or where necessary, calibrated before the testing. The testing has to be done by a skilled person.

Common errors apart from conditioning to be avoided during testing:

- Calibration error & zero error of the testing equipment
- Accuracy error of the measuring instrument
- Stability error (Applicable to reversion/shrinkage, hardness, curing)
- Repeatability error (when the same product is tested using the same equipment, same procedure, same person, on the same day the result should be the same)
- Reproducibility error (Different persons testing same product at same or different places, using same standard procedure, same equipment should give same result)
- Linearity error (e.g. If the heating rate in VST differs, then VST will be different)
- Specimen shape error (those should be as per standard tolerance in dimensions)

The purpose of analysis is to ensure that the product conforms to the quality requirements of the standard followed as well as customer requirements and it will not fail in agreed service life (guarantee period).

For every test result, corresponding process parameters recorded at the time of drawing samples are available. **Comparison of test results** vis-a-vis process parameters is a very useful tool for improvement in quality.

Such a comparison gives us information about the process (if it's consistent giving consistent product test results), if there is deterioration (for corrective actions) and if there' s an improvement of desired test's result (to modify process parameters for better results).

The bests process parameters need to include:

- The collection of all the test results for a particular product.
- A scrutinize of all the test results to find the best and the worst and their respective documentation of process parameters.
- The process parameters responsible for the difference in quality
- The repeating the process as per the best parameters
- A standardization of the process parameters in the form of "process control plan" for future production

POST INDUSRIAL WASTE, THE PROCESS

Today all post-industrial and post-consumer waste materials can be **re-processed** through the extrusion process. Plastic waste from industrial production is becoming more and more valuable in times of rising raw material prices and increasing environmental pollution. We believe that **becoming more sustainable** is an inevitable path for the plastics industry.

Some critical issues to be faced when processing waste materials can be: the high temperatures, the **pressures** involved in the extruder and the **stresses** involved in the recovery and reworking of plastic materials create inevitable degradation processes. These problems greatly limit processing and reuse and have an impact on the processability and technical/ qualitative characteristics of the output products.

Another challenge when it comes to recycling waste materials can be **residual moisture**, which is why an extruder for recycling needs venting and degassing systems to remove not only moisture but also solvents or decomposed materials.

Bausano, with its system, aims at solving process criticalities such as the loss of mechanical properties and the management of the increase in residual moisture of the selected product, which is a critical parameter to be managed during the processing phase.

Case History

A **single-screw E-GO 45/37 line** has just been sold and tested in our test department. It has been designed for regranulation of industrial post-consumer material, in particular, PP and ABS. The customer also requested a further test with glass-fiber reinforced ABS. In this case, the result is influenced by the dispersion and percentage of the filler present in the starting material.

The line has been designed with **volumetric dosing units** for dosing the raw material. The installation of a **degasser** for stripping the volatile substances formed during melting has improved the workability of the material and its technical/ qualitative output characteristics.; an **automatic filter** with operating pressure of up to 600 bar, an **extrusion head** with 16 “spaghetti” holes, a **cooling tank**, a **dryer** and a **cutter** have enabled the re-granulation line to reach a capacity of 200 Kg/h.

Everything has been designed within Bausano starting from the study of incoming materials and the specific requests of the customer; this is the demonstration of how **our lines are very flexible** and can be designed according to the specific needs of productivity and workability of the materials proposed.

Energy costs represent the third-largest cost item in the budget of plastics companies and their containment is a necessity to maintain high competitiveness on the market.
Production machinery, plant lighting and heating systems, and industrial refrigeration systems are just some of the items that contribute to raising the load curve, especially when the company has obsolete and inefficient equipment. The extruder is the most important energy-consuming component of a plastics manufacturing company. A malfunctioning system is not only at risk of failure but also consumes more energy

Designed by our team of engineers, the **Barrel Induction Heating System** is a Bausano technological innovation that allows savings of up to 35% on extruder consumption.

In the process of induction heating, the metal of the barrel is exposed to an **alternating electromagnetic field**, generated by a current-carrying coil. These coils consist of special cable wounds around a metal core. This non-contact process produces **eddy currents** in the material, which in turn produce heat.

The principles advantages of introducing the **Smart Energy System** are:

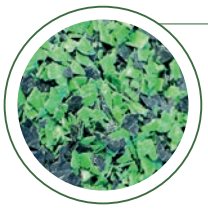
- **Ease of installation** through the opening coil heater
- **Faster heating**
- **Maximum energy efficiency** thanks to electromagnetic induction, which enables the heaters to achieve savings of up to 35%. This is because the thermal energy generated by electromagnetism is not dispersed into the environment but is concentrated within the element to be heated, without the need for any physical contact with the element itself
- **Processability of materials at higher temperatures**, allowing considerable savings in the processing of those materials that require processing at high temperatures - e.g. PO

Through constant investment in research and development and continuous technological innovation, Bausano is a partner for the development of a traceable plastics supply chain.

We want to **actively participate** and transform a currently fragmented production chain (plastics processing chain) into a virtuous circuit and ensure a quality, efficient and cost-effective final production. Our desire is to create a chain of cooperation between those who, like us, are manufacturers of plastic processing machines and those who use our equipment to produce products.

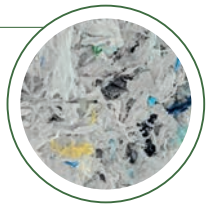
E-GO

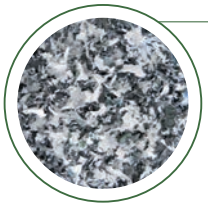
The pelletizing machine for recycling



PP/PE mixed fraction downstream of plastic washing system

Mixed fraction pressed, downstream of plastic washing system





PP flakes for injection molded parts

PE flakes downstream of plastic washing system

bausano
Your Extrusion Allies

PP
PVC
LDPE
HDPE
PE
ABS
PA
WITH GLASS FIBRES
TPE
PC
PVDF
BIOPOLYMERS
EVA

PLASTIC RECYCLING AND RECOVERY

Due to its great use in a wide range of applications, **plastic** assume the role of one of **the main component of solid waste**. Landfill space shortage and a general growing environmentally conscientious society, give the opportunity to processors to adopt new technologies for reducing waste and maximizing recycling efforts.

Wastes from industrial plastics manufacturing are becoming more and more **valuable** in times of rising raw materials prices and increased environmental pollution. A lot of materials and plastics are subject to recycling, the most commonly used are **PVC** and **Polyolefins**. Urban and industrial waste collection always consists of a mixture of three main plastic components: low-density polyethylene (**LDPE**), high density polyethylene (**HDPE**), and polypropylene (**PP**).

New extrusion technology and process design are key factors to grant quality products and investment returns.

Polyvinyl Chloride (**PVC**) is one of the most used **thermoplastic materials** with respect to worldwide polymer consumption. Currently, PVC can be processed into a wide variety of products, such as medical devices, pipes, profiles, floors coverings, and roofing sheets, through various processes and technologies.

In **mechanical recycling**, the materials are ground, remelted, and reprocessed. The high pressure, temperature, and stresses undergone during these steps lead to changes in the polymer structure and properties. This can lead to **degradation**, crystallization, and consequent processability problems, which result from molecular chain scission, branching, and crosslinking, or decreases tensile strength and impact strength.

Also PVC material is subject to degradation. During **mechanical recycling**, PVC presents a highly sensitive environment, involving continuous changes in its morphological structures and properties during processing.

Because of shear stress, the fusion of plastic particles progressively changes the original particle, affecting both physical and mechanical properties of the material, this **instability** can make it lose quality.

In general, reprocessing HDPE and LDPE makes the materials harder to process due to the decrease of **Melt Flow Index** (MFI), which significantly increases melt pressure, extrusion torque, and complex viscosity.

The **challenge with PO recycling** is that the melt viscosity of the materials increases considerably, so the production process needs more energy. Higher viscosity could make recycled PO products difficult to extrude, but alloying some materials together, virgin and recycled, can minimize the changes in MFI.

The melt blending

The best solution is **melt blending** and is one of the most used ways of mechanically recycling plastic waste. It consists of blended recycled plastics with similar types of virgin plastics or different types of recycled plastics in the melting process. Blending recycled plastics with virgin plastics can **reduce cost**, but also the new blended plastics can maintain the equal performance of virgin plastic products. The melt blending technique is the most adapted for the post-industrial scrap thanks to the clear separation of different types of plastics, and a lower level of impurities in it.

Also, for **PVC** the melt blending technique is the solution to the degradation problem, even if it depends on the type of PVC and its former use. Unlike PO, which is similar and mixed, PVC doesn't have a family of plastics to be mixed with, so several tests were done, like mixing it with PMMA or ABS to improve its quality and mechanical properties.

Additives and fillers

It isn't sufficient only to mix recycled and virgin plastics. PO or PVC scraps also need filler **reinforcements**, and they can be natural fillers, like wood, or there are also inorganic fillers, and they can improve morphological, mechanical, rheological, and thermal properties. Every project needs its own custom extruder and mix of fillers, additives, virgin, and recycled plastic.

Feeding system

Before the waste plastic can be processed, it must first be broken down, cleaned, and then divided according to type if it is post-consumer waste. So the plastic waste must be regrinded and then it can be transferred via conveying lines and feeders to the compounding process. Any plastic material to be recycled can be heterogeneous in shape, dimension, and bulk density.

Downstream

One of the challenges of recycling waste material can be the residual moisture, for this reason, a reprocessing extruder line needs **degassing** and **venting**, which are carried out during various extrusion processes to remove not only moisture, but also, monomers, oligomers, solvents, or decomposed materials.

After the degassing phase, there is a **vacuum pump** and a **melt pump**, then the material will pass through a **screen changer**. This is fundamental to remove any contamination of plastic that a manufacturer can encounter with waste before the pelletizing phase.

BAUSANO AND THE 2030 AGENDA

Health and well-being, decent work and economic growth

Ever since it started out back in 1946, Bausano has always believed in the close synergy between business and society and has sought to enhance the internal and external environment. Over the years, this has allowed us to become a company that people want to work for and partner with. Values such as environmental, social and economic sustainability are already an integral part of our culture.
In fact, throughout the years, projects and problems have always been addressed from a Triple Bottom Line perspective, that is, by analysing critical issues and benefits in the above-mentioned three main areas of sustainability. By building on the heritage described above, Bausano has decided to make a commitment to actively contribute to the 2030 Agenda by working towards some of the 17 goals, namely those most consistent with the company's business.

The goals and thematic areas on which Bausano is and will be working on in particular are:

Social, Environmental and Economic

With its production of extrusion lines for plastics, Bausano supports these goals, first and foremost internally. External support is also provided through social, environmental and economic projects that are not only about pursuing monetary profit. It is important to take action on all three levels, taking into account not only the positive effects generated but also the negative ones. As a concrete example, an action taken on a social level can have virtuous impacts, creating economic and environmental value. We hope that this will continue over time, thus allowing for sustainable development in the region as set out in the 2030 Agenda.

BAUSANO FOR SOCIETY

Corporate social responsibility has always played an important role in our choices. We strive to improve in this area every day. When we began working towards achieving some of the goals of the 2030 Agenda, we embarked on a journey – to be more precise, it is a natural continuation of a process that began many years ago – which is a long-term, demanding and complex challenge for our company.
At Bausano, we have always focused on creating a more equitable and more ethical business.

But what exactly does the word “ethics” mean?

The creation of a corporate culture based on rules, standards, codes or principles that provide both individual professionals and the company’s internal teams with guidelines on how to adopt moral and correct behaviour in all situations. In fact, Bausano always keeps its values in mind in relations with its stakeholders.

BAUSANO FOR THE ENVIRONMENT

In many cases, environmental pollution can be traced back to corporate activities in both the input and output phases. It is a key factor, but it is not the only one. In order to change things and make progress towards achieving the goals of the 2030 Agenda, we need to take action in a number of areas. The main ones are: the use of natural resources (water, energy and land), harmful emissions, waste creation during production and the overall impact of a product throughout its life cycle.

BAUSANO AND ECONOMIC GROWTH

This is a very important Goal for the 2030 Agenda and for Bausano. In fact, this is a cross-cutting goal covering all three areas of sustainability. The activities we have carried out in order to meet the target of this goal do not only concern the economic growth of our company and of the area in which it operates, but also environmental and social factors. It is for this reason that focusing our research, development and innovation efforts towards achieving environmental sustainability is a basic principle for building a company that is able to bring about virtuous changes and prioritise resilience. Therefore, for Bausano, tackling Goal 9 of the 2030 Agenda involves strengthening and continuing to conduct in-house scientific research in the pursuit of excellence.

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