

# TWIN-SCREW COROTATING EXTRUDER A FLEXIBLE SOLUTION FOR ADVANCED RECYCLING

By Icm San Giorgio SpA

## INTRODUCTION

Due to its great use in diverse array of applications, plastics represent one of the main components of solid waste. Plastics is derived from petroleum sources and is non-biodegradable. Given landfill space shortage and a general growing environmentally conscientious society, processors have the opportunity to adopt new technologies for reducing waste and maximizing recycling efforts. Advantages secured by an improved recycling activity are: waste reduction, cost decrease of the final product, energy consumption reduction, environmental protection and oil savings.

Starting from a waste/scraps (PET, PVC, HDPE, LDPE, PS, PA and ABS are the most commonly recycled plastics), through plastics recycling it is possible to obtain a new end-product with high technical features.

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

In the plastic recycling industry the use of **co-rotating extruders** is becoming more and more a winning solution compared to traditional technologies (such as single-screw extruders) in facing most of the issues and challenges that plastic processors have to address today.

**Icm San Giorgio** ([www.icmasg.it](http://www.icmasg.it)), a leading Italian supplier of co-rotating extruders and compounding technology, has developed advanced recycling systems based on **co-rotating extruders** dedicated to the recovery of single polymers (HDPE, PA, PET etc.), miscellaneous post-consumer materials (mixed plastics) highly contaminated plastic industrial waste (eg. Plastic scrap rich of ink or other volatile elements ...), general scraps (eg. tyre rubber). Taking most of their technical features from its MCM – “high torque” family, these specially designed extruders use, among other features, a particular degassing and filtering systems able to treat demanding scrap materials that are treated to obtain quality materials ready for new applications.

## EXTRUSION PROCESS

Pellet is the typical end product of a recycling extrusion line, but it is not the only one.

By using “Direct extrusion lines” it is possible to recycle plastics and to directly extrude the final product (sheet, foil, pipe, profile).

Extrusion process involving waste/scraps requires high performances mainly in mixing and venting steps.

Due to the low mixing entropy of the plastics it will be necessary to introduce into the system a very high quantity of energy. Simple heating is not enough for good materials dispersion.

The extruder’s screws must be therefore capable to transfer high stress to the plastics flowing into their channels.

The wide range of the recycled plastics, added to the different MfI values available on the market, further complicate the situation.

To obtain a durable products starting from a recycled material it will be necessary to modify and increase its properties.

Only after having clearly understood which kind of product must be produced on the recycling extrusion plant, it is possible to list the relevant properties and to study the recipes necessary to reach the production target.

Materials normally mixed in a polymeric matrix are the following:

- **mineral fillers** (to reduce the costs, increase the stiffness and the dimensional stability)
- **fibres** (to increase the stiffness, the strength and the electrical properties)
- **impact modifier** (to increase the toughness)
- **nucleants** (to modify the crystallinity)
- **lubricants** (to help the process)
- **compatibilizers** (to create chemical bonding)

These components need to be mixed properly inside the plastic to obtain the desired results.

The quality of the final products therefore depends from the obtained distributive and dispersive mixing.

Mixing represents a critical phase of the plastics recycling process.

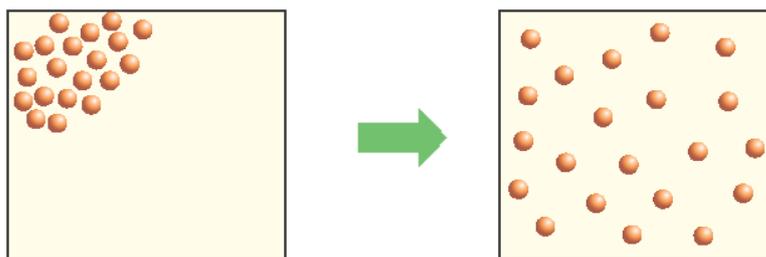
## **MIXING**

Co-rotating twin-screw extruder is capable of an high mixing quality (it is a mixer).

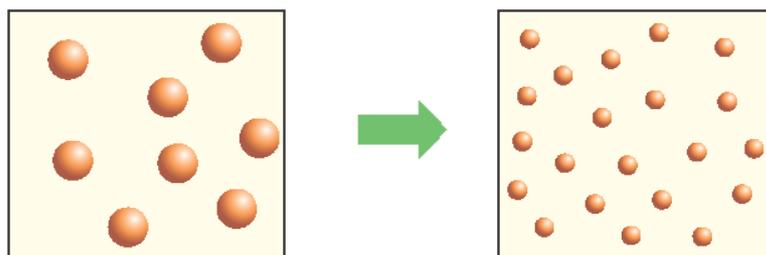
We cannot say the same for the single-screw extruder, which main task is to create enough pressure to extrude the material throughout the die (it's mainly a pump).

Aim of the **distributive mixing** is to obtain a final uniform composition of the extruded products.

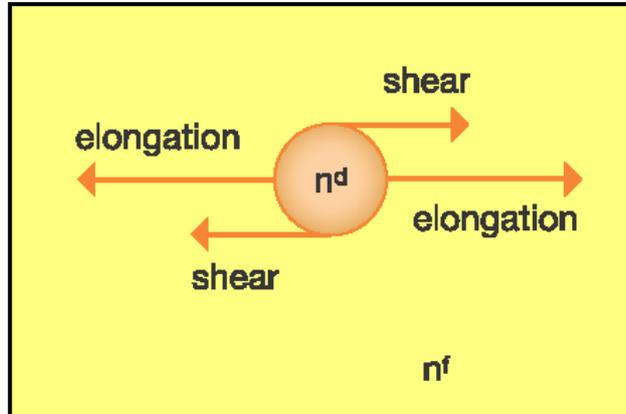
The figure clearly shows this concept (white area = polymer, black pellets = particles to be mixed).



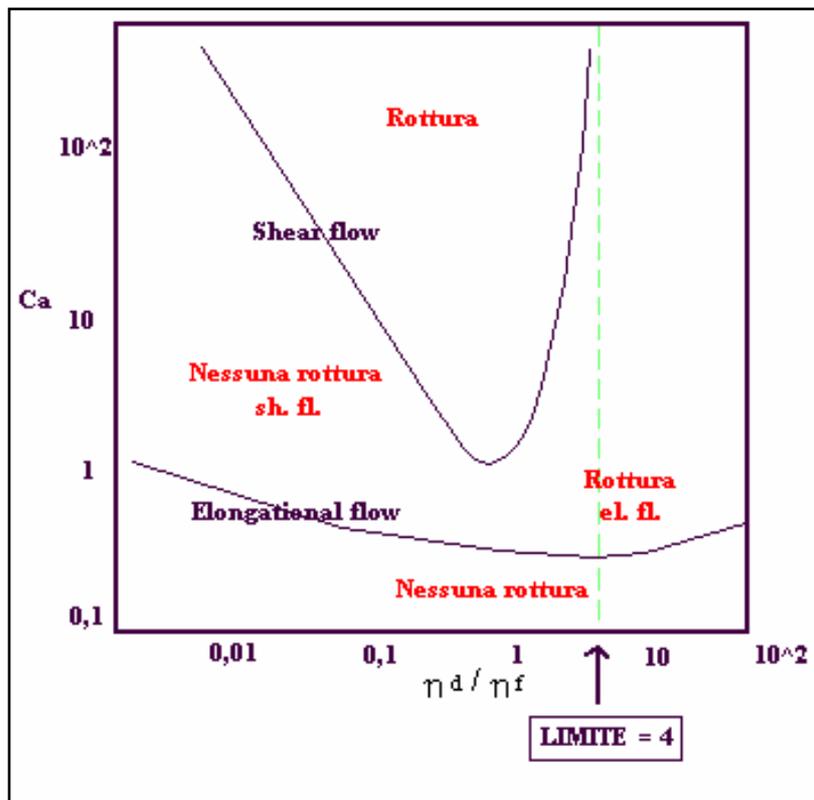
A good **dispersive mixing** is much more difficult to obtain and it aims to reduce agglomerates size or molten polymer droplets size, to a defined dimensions.



By processing recycled materials, it frequently happens that two kinds of liquids (plastics in molten form) with different rheology must be mixed.  
By means of the extrusion screws, shear stress and elongation stress are transferred to the material particles, which must be dispersed.



If the applied stresses are higher than particle cohesive forces, droplet is deformed and breaks, creating smaller particles size (dispersion).  
The intensity of the requested stress depends on the stress type (shear/elongation) and on the viscosity ratio of the plastics to be mixed.



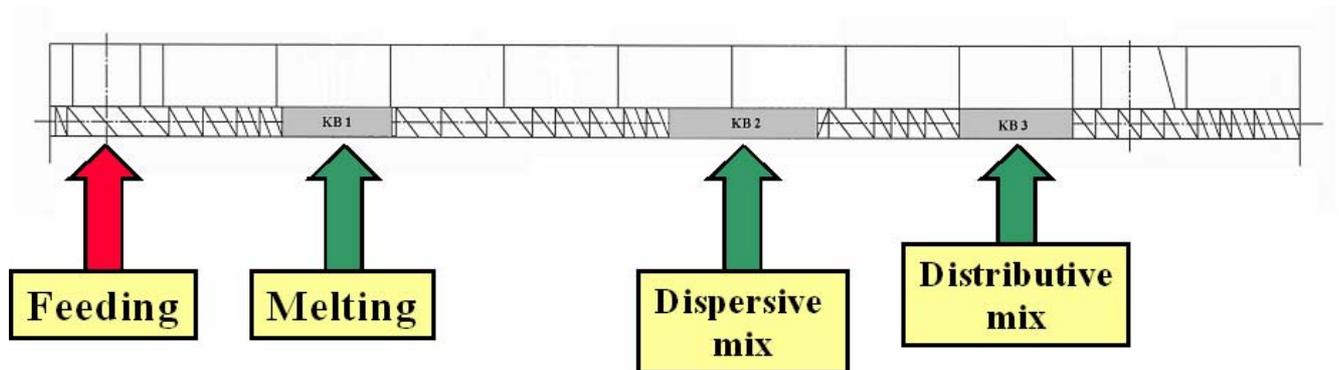
Modular screws of the co-rotating twin screw extruder, consisting of a well defined sequence of **conveying** and **kneading elements**, make possible an accurate calibration of the intensity of the shear and elongation stresses along the machine axis.



Conveying screw element



Kneading



A typical screws configuration for recycled plastic includes the following sections: material feeding, melting, dispersive mixing and distributive mixing.

The use of compatibilizers to limit **coalescence** is essential. This phenomena causes a de-mixing of the final product that needs to be avoided.

### **DEGASSING**

Degassing is another essential step in the plastics recycling process. In this phase the volatiles developed by the extrusion process are extracted.

There are two extraction mechanisms in the extrusion process:

- 1) Molecular diffusion to the polymer melt surface
- 2) Expansion: bubbles containing the materials to be removed are formed inside molten polymer; they expand, collide one against the other and increase their dimensions until the melt surface is reached, where they break releasing their content.

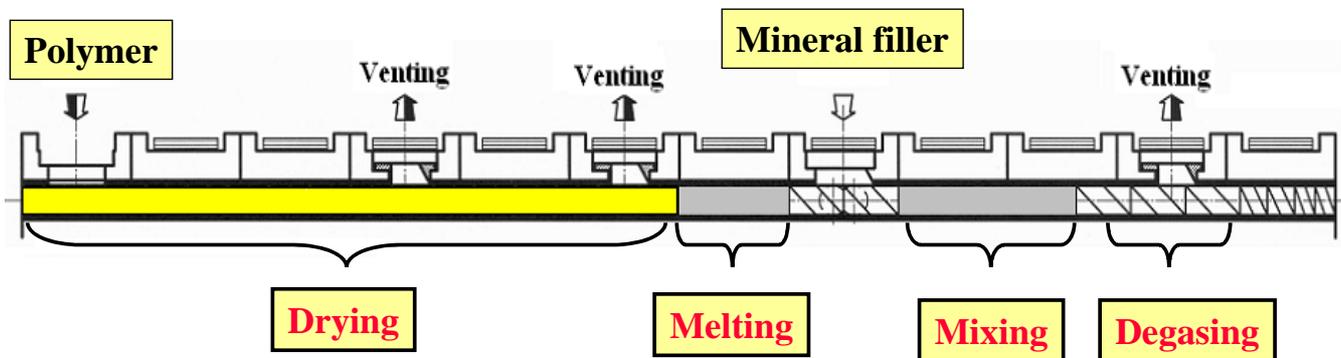
Performance of the degassing step is adjusted by modifying the melt temperature, the residence time, the screw rpm and the filling ratio of the screws channel closed to the venting dome.

When increasing the melt temperature, the viscosity decreases helping the bubbles formation and the expansion.

An higher residence time increase the performance of the molecular diffusion mechanism. Increase of screw rpm reduces the residence time on one hand, while improve layers renewal on the other hand (pay attention to the degradation!!). A decrease of the screw filling ratio, increases the expansion of the melt and therefore the performance of the degassing process. A “fine tuning” of the operational conditions and – eventually – of the screw configuration are requested to obtain the highest performance.

With this approach it is possible to maximize the melt expansions inside the screw, avoiding relevant leakages from the venting dome.

While on a traditional extrusion/compounding line only one degassing point is installed, two or more volatiles extraction points are provided in a recycled materials process.



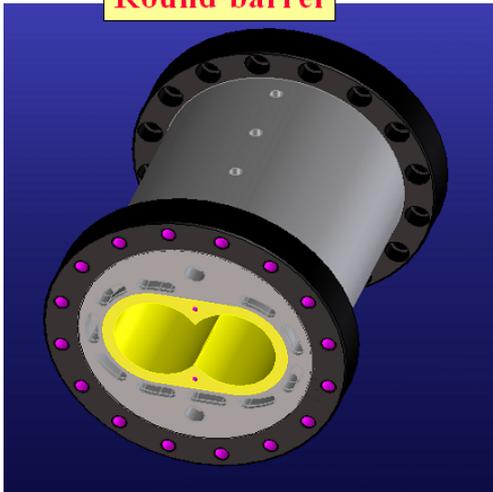
## **FLEXIBILITY**

Machinery flexibility is a **MUST** when processing recycled plastics. The use of different plastics and different viscosity grade requires the possibility to easily modify the extruder configuration and the operational conditions set-up.

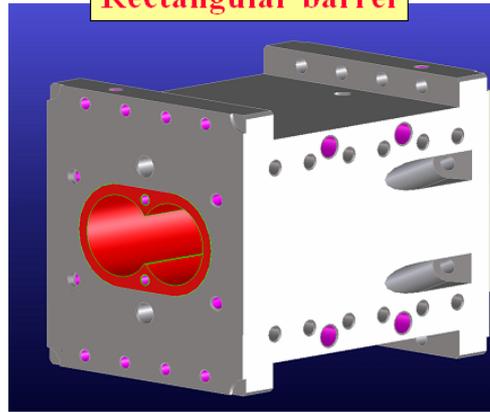
The co-rotating twin-screw extruder is the most flexible solution available on the market both from the re-configuration point of view and the possibility to “play” with its working conditions (throughput, screw rpm, barrel temperature).

The extrusion barrel of co-rotating twin-screw extruder consists of different sectors having a length of 4D, available in two different shapes (round or square).

**Round barrel**

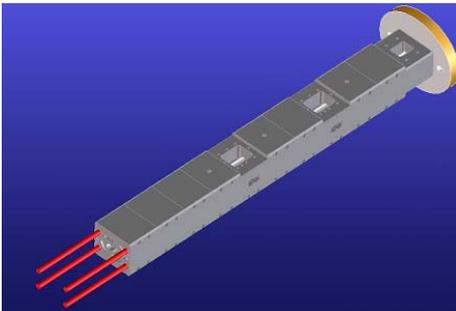


**Rectangular barrel**



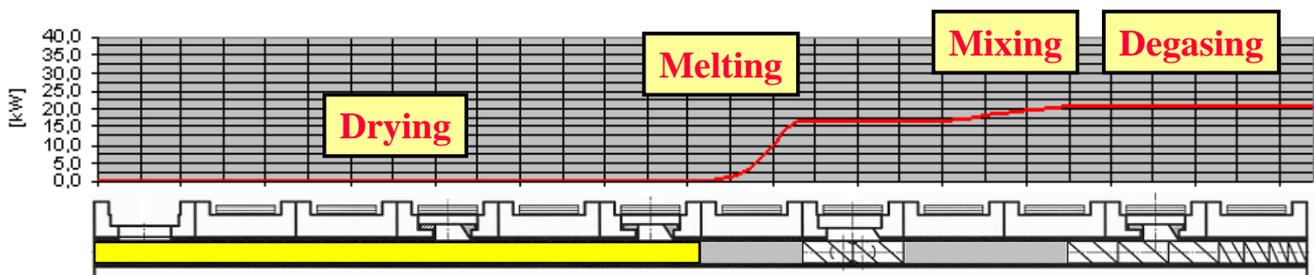
Barrel re-configuration is simple and quick: on the medium/small size extruders, the different barrel sectors are fixed by four tie-rods. By releasing 4 bolts at the end of the extruder it is possible to remove the sectors and prepare a new configuration according to the new process request.

Starting from 60 mm. Extruder size, the different barrel sectors are connected together by bolts.

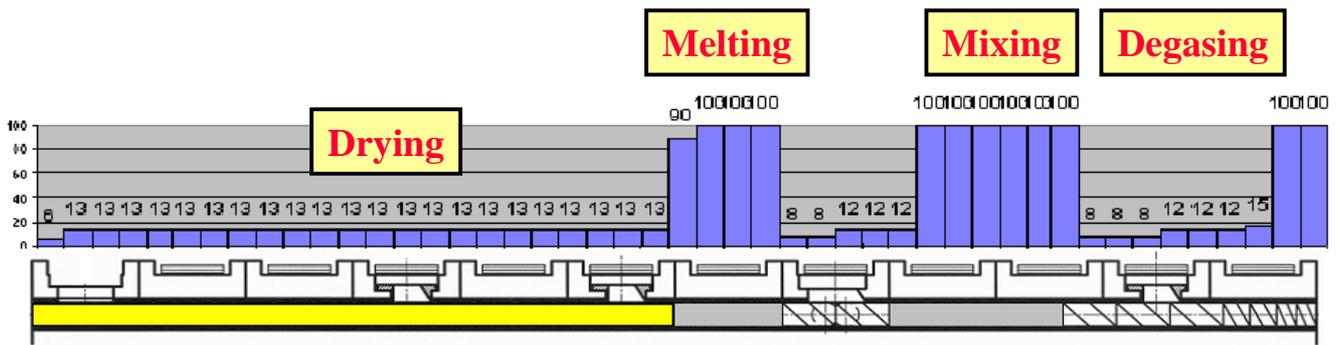


The same for the screw configuration. The different screw elements are assembled on a splined shaft and they can therefore be easily removed and quickly re-assembled.

With a well defined screw configuration it is possible to adjust the energy transfer to the process, limiting useless energy losses (energy is transferred where it is needed!!!).



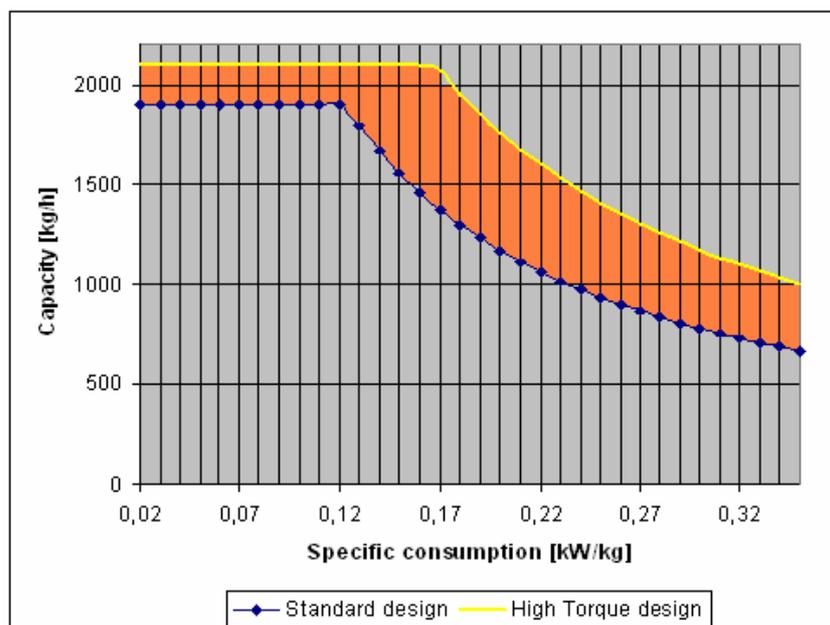
Unlike the single-screw extruder, which works normally with a fullfilled channel with consequent high-energy consumption, the filling ratio of a co-rotating twin-screw extruder is variable.



### SPECIFIC EXAMPLES

#### Polyolefins's waste (eg HDPE, PP) with different melt flow index to mix

When there are several POLYOLEFINS waste **with different melt flow index**, the recycling system needs to grant an homogeneous mixing in order to improve quality and production yields. In this case, in addition to performing degassing units, it is often necessarily to transfer to the melt a high degree of specific energy and therefore there is a need for high torque extruders. Nor single or counter-rotating extruders can do what a “high torque” co-rotating can deliver here. In addition, the material performance can be improved by adding fillers or other ingredients for industrial use in demanding industries such as the automotive or construction.



## **rPET**

PET is one of the most recycled polymers.

When recycling PET it is necessary to cope with its different degradation possibilities (mechanical, thermal, oxidative, hydrolytic).

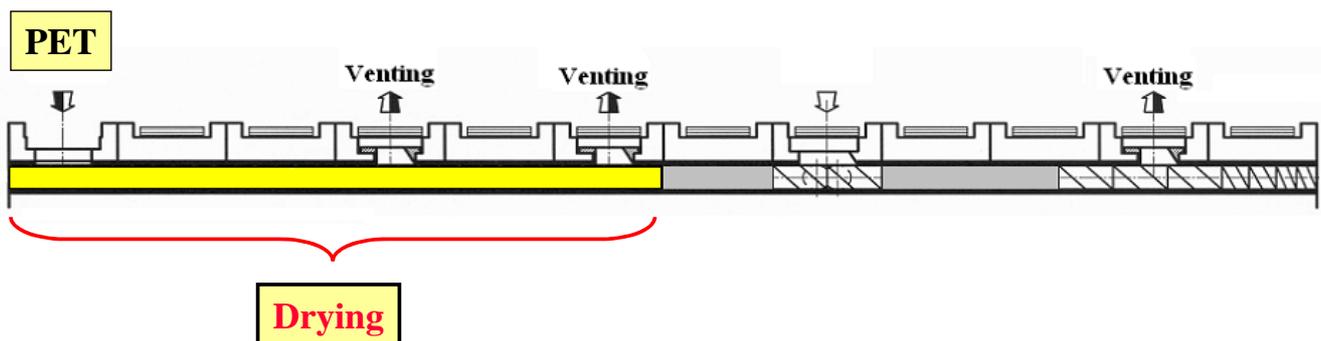
Hydrolytic oxidation is the most dangerous degradation process and it can produce a severe reduction of molecular weight, viscosity and so the mechanical properties of the material.

PET is an extremely hygroscopic material, which quickly absorbs the air humidity.

During the extrusion process it is necessary to limit the stress transferred by the screws (mechanical degradation), but it is most important to extract the humidity from the material before the hydrolytic degradation process will begin.

PET dehumidification is normally done separately and this requests a previous material crystallization to avoid its softening inside the dryer ( $T_g = 75^\circ\text{C}$ ).

Using a co-rotating twin-screw extruder, dehumidification can be done in-line, inside the extruder.



Further to the advantages of a continuous process, this solution guarantee a 50% of energy saving in the extrusion process (crystalliser and dehumidifier are no more required in the plant).

Other advantages are:

- possibility to feed flakes (a densifyer is therefore not required)
- reduced plant maintenance (dehumidifier, crystalliser and densifyer are not present)
- no material losses due to a formulation change

## **PLASTICS BLEND**

Mixing PET with other plastics or additives/fillers/reinforced materials it is possible to obtain new materials having interesting properties.

One of the most popular is PET/HDPE blend where both materials can be from recycling source.

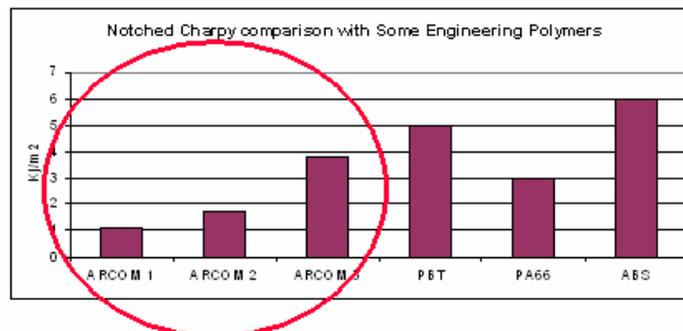
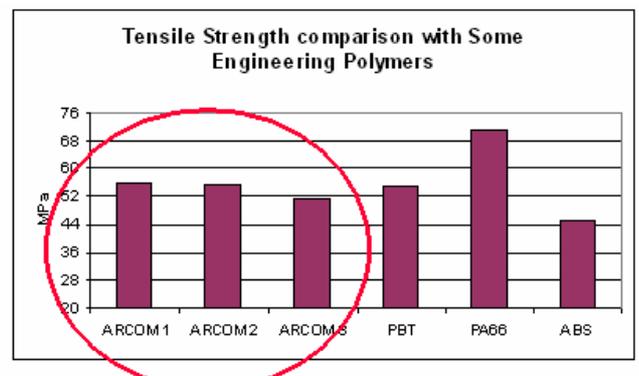
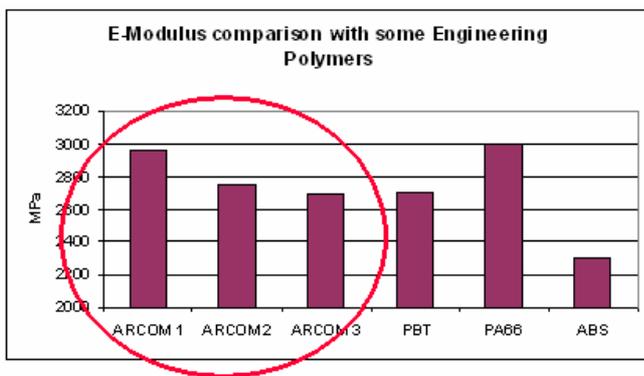
It is less brittle than PET and it does not require a dehumidification process.

It is stiffer, stronger, better flowing and faster cooling than HDPE.

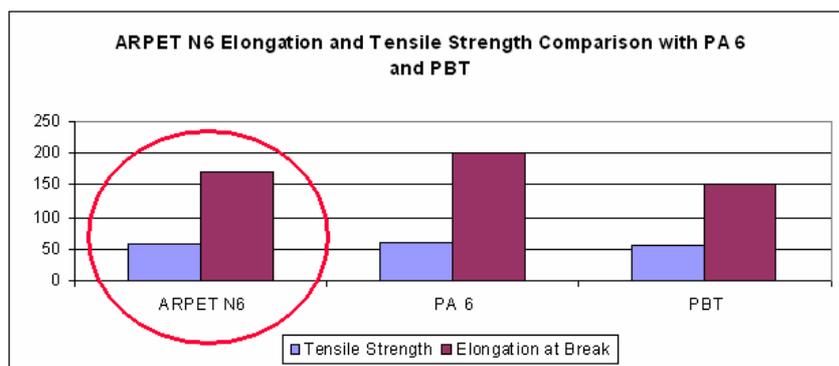
This blend could be used in injection moulding process, granting faster working cycles.



The following diagrams shows some of the mechanical properties of three different kinds of blend developed by an our customer compared with other engineering plastics (PBT, PA66, ABS).



Mixing recycled PET with a small quantity of a “special” chemical additive studied by the same customer, it is possible to obtain extremely interesting performances.

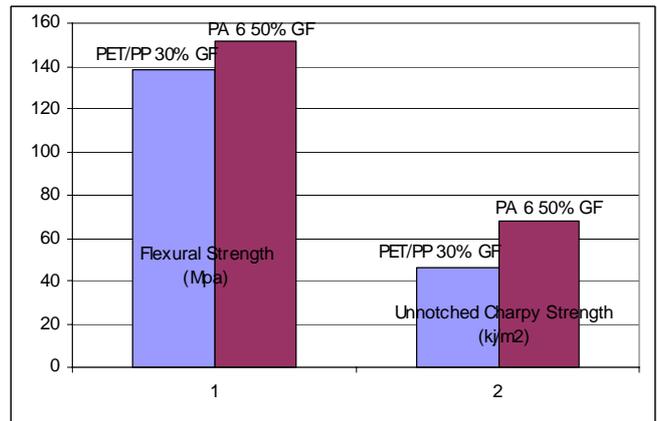
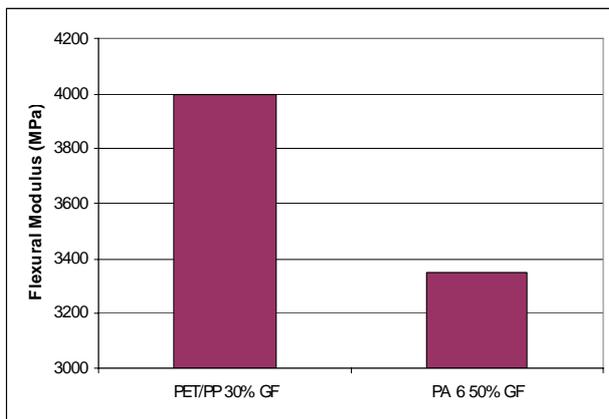


Other interesting application studied by the same company are:

- compound of recycled PET, PE and 15% fiber glass that successfully replaced the standard PA.6 + 30% of fiber glass for construction sector products
- compound of recycled PET, PE and 15% fiber glass for electrical products
- compound of recycled PET, PP, elastomer and 30% fiber glass for handles of heavy duty crates



The following diagrams show a comparison of mechanical properties of recycled PET + PP + 30% fiber glass compound and PA.6 + 50% fiber glass.



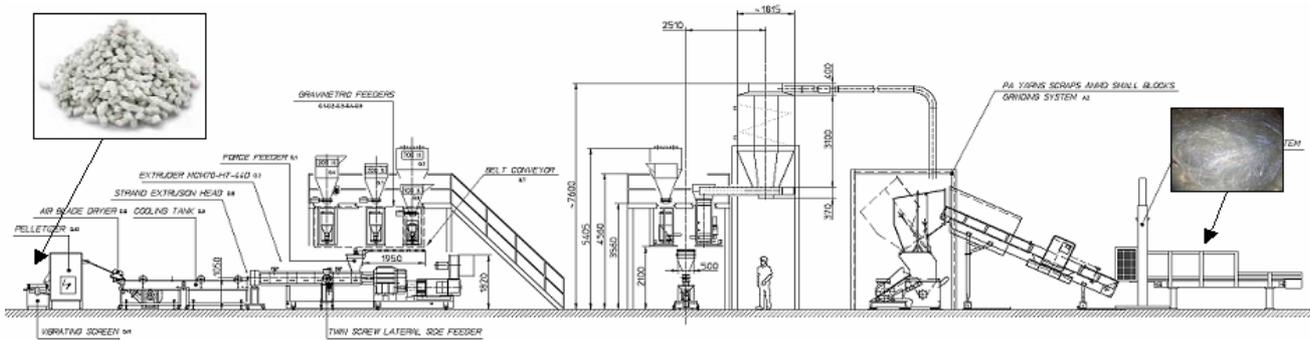
**LOW BULK DENSITY scraps such as AGRICULTURAL FILMS or PA YARN**

Another interesting possibility granted by our technology is the LOW BULK DENSITY recycling, starting from bales, to obtain a reinforced compound.

During the engineering of the line suitable for the above-mentioned purposes, the critical point is represented by the capability to feed the material with enough accuracy.

Mass quota of the volatiles present in the recycled material cannot be constant.

For this reason flexibility in setting up line operational conditions must be granted is a must.



**CONCLUSIONS**

Energy saving trends together with the general need to find a “new” life for wasted materials and production scraps and to obtain technical products at a competitive prices are the major bias supporting the penetration of such technology in the market.

The possibility to recycle plastic materials of different kind using a very performing technology such as co-rotating extruders is a great opportunity for existing processors already involved in plastic recycling to upgrade their current systems and for “new comers” willing to exploit the market potential that is visible in many countries and that are well encouraged by local governments that have set *sustainability* as a strategic element of their political agenda.

*Icma San Giorgio SpA ([www.icmasg.it](http://www.icmasg.it)) is an Italian based company and is part of a family owned Group with more than 100 years of industrial history and with interests in the mechanical and metallurgic fields.*

*With more than 40 years experience in plastic machinery, Icma is today a leading supplier of **co-rotating extruders** and **complete turn-key extrusion systems** for the production of **compound, masterbatch, foils and sheets** where the use of the co-rotating technology gives a competitive advantage. All key parts of each extruder (screws, barrels and gear boxes) are exclusively manufactured by Icma granting therefore a constant high quality of the final system.*

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