An industrial tool

Ludovic® has been designed with the support of an industrial pool since 1998.
For more than twenty years, Ludovic® is improved for enriching its features
Its packages really suit to SME or groups with integrated R&D centers.,

Suitable packages

Different packages are available with the Ludovic® software. They all include :

Training

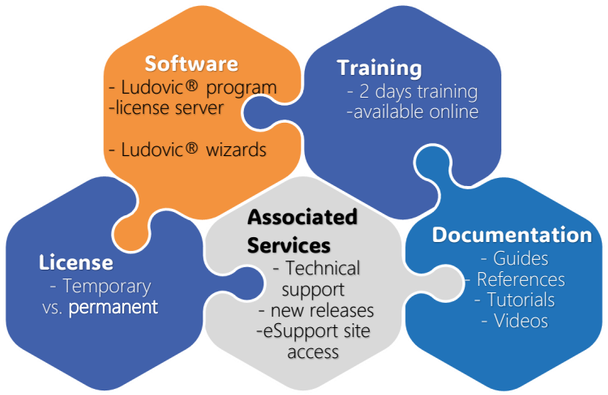
Video-training and on-site training are available to support your use of the software.

Associated Services (technical support)

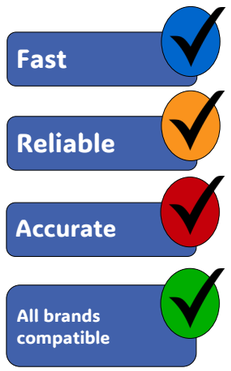
Each license comes with Associated Services, to support your Ludovic® experience and drive you in your first applications and simulations.

For fastening the ROI

With such support and services, we ensure a fast ROI. Indeed, getting started with the software is thus made faster and all of your applications can be easily integrated in Ludovic®.



Access / License	Single	Group	Enterprise	Corporate
Ludovic® GUI	1	5	7	10
Ludovic® Computation	1	2	3	5
Ludovic® Identify	1	4	5	8



Developed with :

INRAE science for people, life & earth — MINES PARIS | PSL | Cemef

Replace **trial & error** with numerical simulation to save **time & money**

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Ludovic®

Simulation for twin screw extruder

SCIENCES COMPUTERS CONSULTANTS

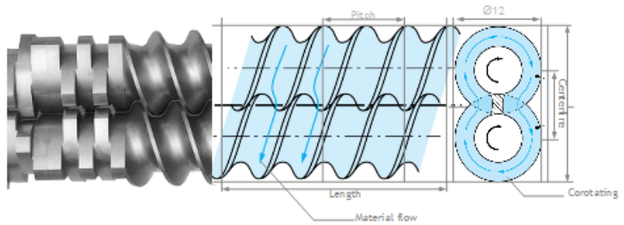
The Virtual Extrusion Lab

Advanced Tools for optimization

Make simulation the driver of your extrusion process developments

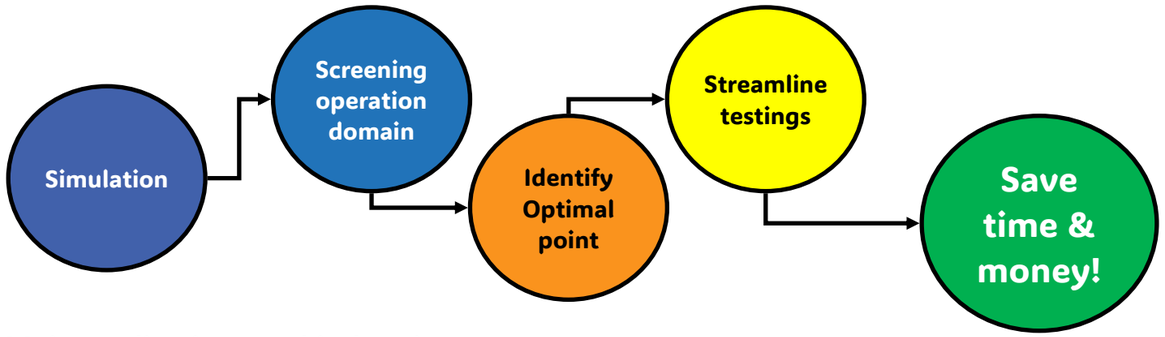
Simulation is strong enough to support your twin screw extrusion process developments and :

⇒ Streamline tests
⇒ Optimize process/Material
⇒ Save time & Money



Streamline tests,

Ludovic® is a numerical simulation software aimed at computing the **material behavior evolution and the process efficiency**. In a few seconds, Ludovic® identifies the optimal configuration to match your criteria.



Main applications and industries

The Ludovic® software is well suited to tackle multiple industrial and R&D topics, like :

Formulation

For anticipating the product behavior according to its components and main characteristics

Reducing time to market

Ludovic halves the needed tests while lowering the costs and improving the quality

Process optimization

An easy analysis of the different screw profiles help in seeking for the most suitable configurations

Scale-up

Provides the right tools for screening large functioning domain and scales extrapolation

Industrial line support

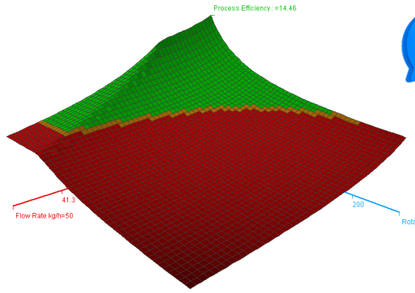
Helps in troubleshooting by providing an in-depth analysis of the process

Advanced tools

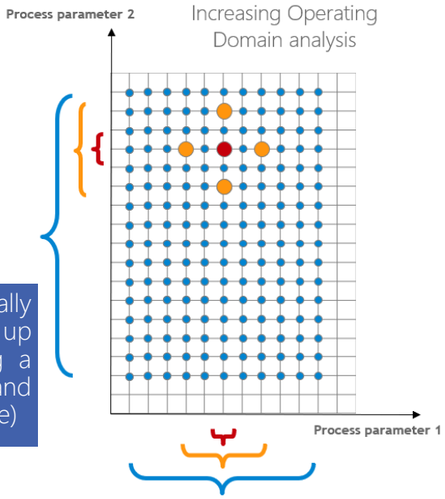
The virtual extrusion lab holds many tools, efficiently designed to support your process development, with :

Virtual Design of Experiments

Screening a large functioning domain in a few minutes is possible. Optimal point is easily identified by the consideration of several criteria.

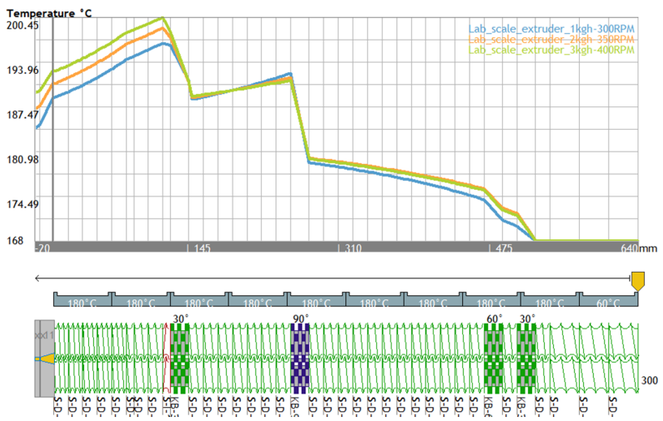


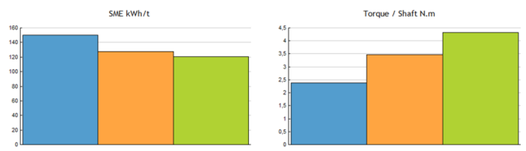
This feature is really suited for scale up applications (determining a new screw profile and conditions at a larger scale)

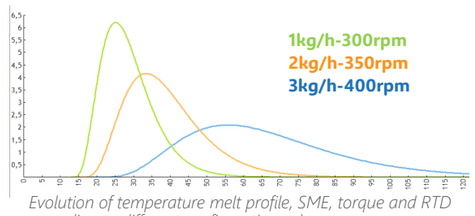


Multi-results comparison

Multiple configurations are easily compared to immediately control the impact of screw design or operating conditions on the material behavior.







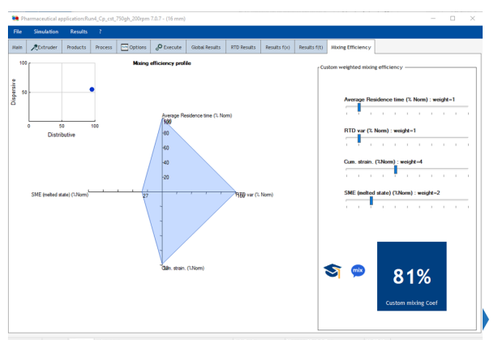
Evolution of temperature melt profile, SME, torque and RTD according to different configurations above
Mixing efficiency matrix below

Advanced Control Interface (ACI)

Specific ACI is used for taking into account real experimental data. This tool allows to get results closer to experimental values according to your own data.

Mixing efficiency calibration

Ludovic® includes a specific matrix for quantifying the process mixing efficiency. Comparative analysis allows to identify the most performant configuration.

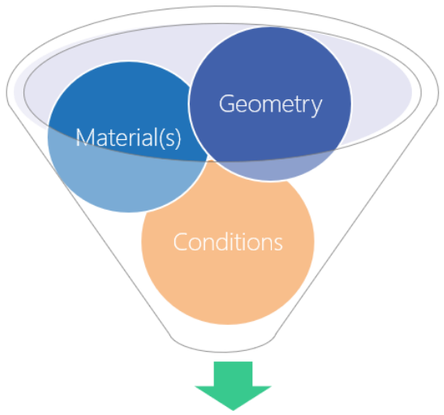


Analyze the twin screw performance — Process focus analysis

Thermo-mechanical analysis : for determining the twin screw performance

Ludovic® manages the twin screw process according to the extruder geometry (including complex screw profiles), product characteristics (multi-components can be simulated) and operating conditions. Input data are easily set-up in the user-friendly environment to describe the process and provide main trends about:

- The material history
- The process performance



Screw design 100% customizable : screw elements are generated from a generic library. They are then stored in appropriated libraries for being re-used

1D/2D model is embedded into a software environment. Input data feeds the software for offering predictive results in about 10 seconds.

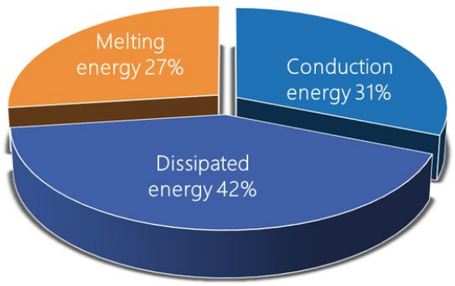
Geometry
Main characteristics of the extruder and screw profile description - compatible for any brands/models

Material(s)
Thermal and mechanical characteristics of the material(s) and additive(s)/filler(s)

Operating conditions
Screw speed, flow rate of feeders, temperature of barrels regulation

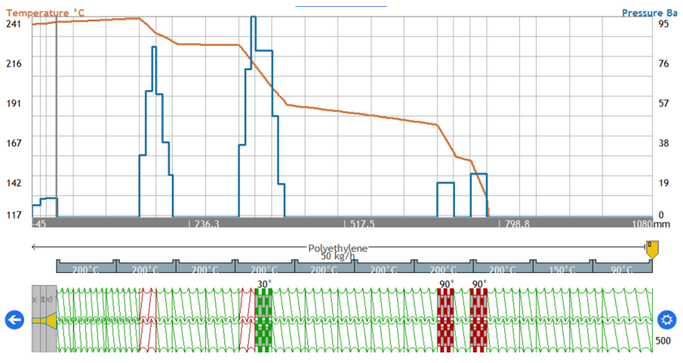
Process performance

Ludovic® computes the energy balance, used to determine the process efficiency. Torque, energies, power… are computed and compared for offering relevant and key data.



Material Thermo-mechanical history

Temperature, pressure, shear, viscosity, filling ratio (and many others results) are computed along the screw profile for an easy visualization of key data.
Impact of screw elements is immediately displayed to highlight main zones of pressure, shear and temperature peaks.
Melted product temperature and pressure profiles are shown on the figure below.



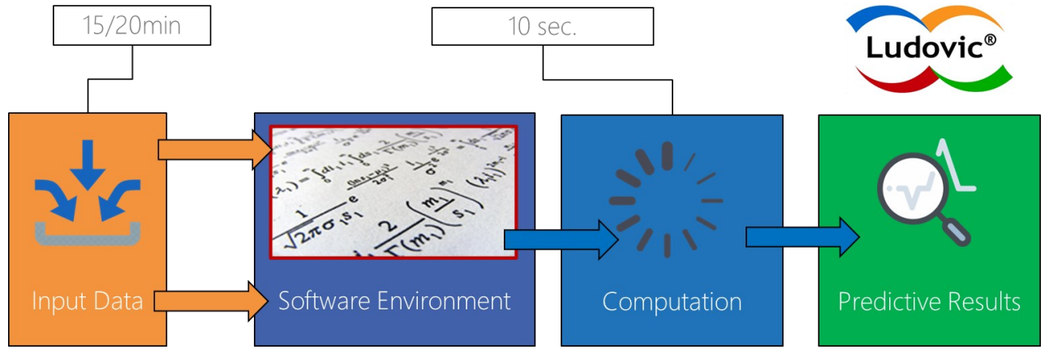
Target industries

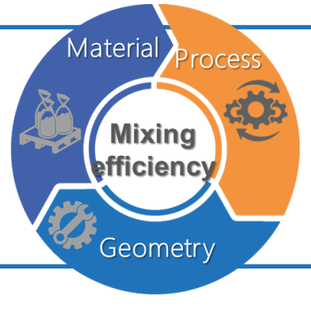
Wherever twin screw are used, Ludovic® can be beneficial

- Plastics industry, thermoplastics, polyolefins, ….
- Compounding
- Agro food
- Masterbatches and high fill material
- Energetic materials, battery, slurry…
- Building & construction, PS, flame retardants…
- Cables
- Chemical industry, integrating complex reactions
- Pharmaceuticals, especially for HME

Process screening in a few seconds

The Ludovic® software is a numerical simulation software aimed a computing the **material behaviour evolution and the process efficiency**. Performing a thermo-mechanical simulation, Ludovic® **opens the twin screw black-box** to highlight the main phenomena and provide an in-dethp understanding of the process, in a few minutes.





Mixing efficiency

The challenge in the twin screw design is to design the most effective process for mixing.
With advanced tools, Ludovic® provides method and data for optimizing the twin screw extrusion process.

Industrial Applications

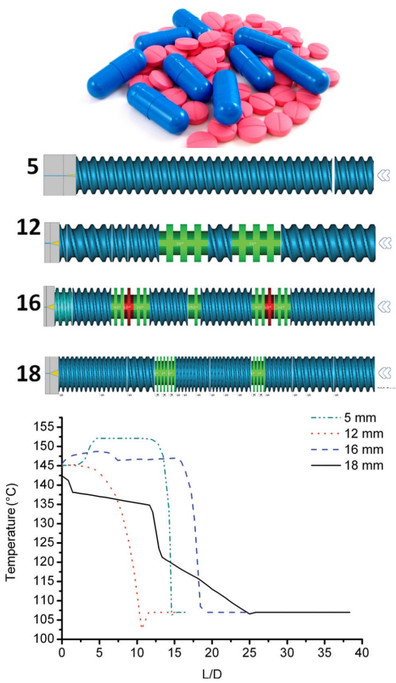
HME Application : From lab to pilot scale

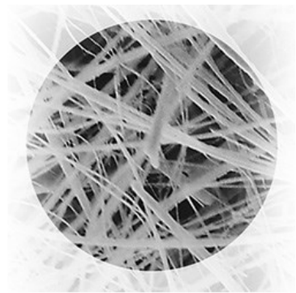
In Pharma industry, the main concern is the availability of **API (Active Pharmaceutical Ingredient)**, used for manufacturing tablets and pills.
It is thus necessary to set a proper process to develop a melt-extruded product, with the optimization of the crystalline drug in early product development.

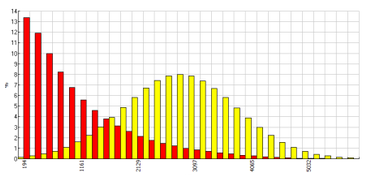
Challenge
API is really sensitive to high temperatures. Mastering the melted material temperature profile in the process, especially in the scale-up phase is achieved with the Ludovic® software.

Inside Ludovic®
Ludovic® is used for the scale-up process, with a specific focus on energy distribution and temperature profile. Simulation shows high potential to identify high-energy intake spots. Ludovic® provides key data for adapting screw profiles to the pharma industry requirements. Scale up is supported using the Ludovic® specific® tools (pharma wizards and virtual Design of Experiments for QbD analysis).

From « Modeling of the Impact of Extruder Configuration on the HME Process and Product Characteristics during Scale Up », 2013, AAPS San Antonio, by K.G. Wagner and D.E. Zecevic







Evolution of GF size distribution in a specific screw element in Ludovic®

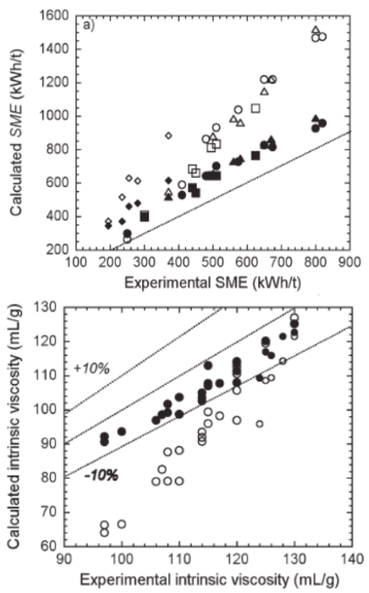
Glass Fibers : How to compute the GF length

Glass Fibers (GF) are compounded with polymers to enhance their mechanical performance. This performance improvement strongly depends on the GF length. The longer the fiber is, the more resistant the material.

Challenge
The stake is to monitor and control the GF length in TSE by the integration of a theoretical model of fibers breakage.

Inside Ludovic®
Ludovic® now integrates a unique model of GF evolution computation. It allows to evaluate the fibers size evolution along the process, according to the shear distribution. An initial GF size distribution is defined as an input (in yellow, on the left figure).
Ludovic® then computes the evolution of GF size distribution (in red, on the left figure) to evaluate the final fibers size distribution.
As a result, Ludovic® provides an average GF size in each mixing area of the TSE.

Agro food extrusion
Predicting starchy product degradation



Extrusion of starchy product remains complex as it this process depends on the evolution of the microstructure (loss of the grain structure, degradation of amylose and amylopectin chains…)

Challenge
The influence of Specific Mechanical Energy (SME) on the material intrinsic viscosity is observed to predict the starch transformation. Viscosity and SME are indeed considered as reliable markers of the starch reaction.

Inside Ludovic®
Computations of SME and intrinsic viscosity are performed with and without coupling. Comparison with experimental results shows a good match (see left figure).
Coupling SME and viscosity allows a qualitative analysis to anticipate the evolution of the starchy product reaction.

From « Importance of coupling between Specific Energy and Viscosity in the Modeling of Twin Screw Extrusion of Starchy Products», by F. Berzin, A. Tara, L. Thigzert, B. Vergnes

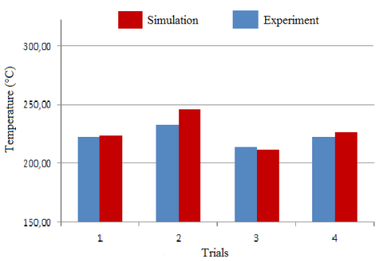
Thermoplastics & Wood fibers

Wood and natural fibers offer a broad range of technical advantages for reinforcing polymers : lighter than glass fibers and capable to reach high resistance levels.

Processing such fibers is challenging as they require an energy high enough for a good dispersion/distribution, but low enough to make sure the fibers are not burnt (as they are sensitive to temperature increase).

Challenge
The Ludovic® software is used to get relevant data about the energy (SME) and the temperature (of the melted product). SME and temperature thresholds are used as target for defining the potential operating window, according to the extruder/material characteristics.

Inside Ludovic®
Temperature, energies, residence time and SME of both experiments and simulations are compared. Both trends are close, the Ludovic software is thus used to identify the optimal configuration and generate scale up solutions. The virtual trial campaign helps in **cutting down tests and costs from 50%.**



Temperature comparison, between simulation results and experimental measurements