Optimization of coat-hanger melt distributors for the wire coating process

e-mail :
nadhir.lebaal@insic.fr
http://www.enstimac.fr
http://www.insic.fr

N. Lebaal1, F.M. Schmidt2*, S. Puissant1 and D. Schläfli 3

1Institut Supérieur d'Ingénierie de la Conception (GIP-InSIC), 27 rue d'Hellieule, 88100 Saint-Dié-des-Vosges, France - nadhir.lebaal@insic.fr; stephan.puissant@insic.fr
2 Ecole des mines d'Albi Carmaux (ENSTIMAC) , Centre de Recherche Outillages, Matériaux et Procédés «CROMeP», Campus Jarlard- Route de Teillet 81013 Albi Cedex 9, France - fabrice.schmidt@enstimac.fr
3 Extrusion Maillefer SA Route du bois 37 - Ecublens – Switzerland - daniel.schlaefli@maillefer.net

Introduction

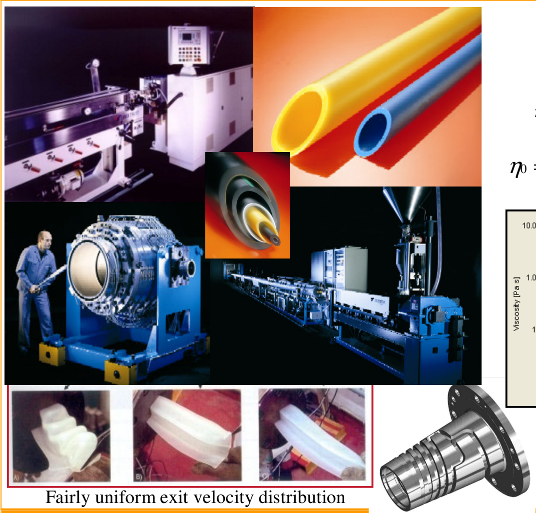
❖ The objective of the rheological design of extrusion dies in the wire coating process is to distribute the melt around the conductor uniformly.

❖The primary objective of the geometrical design of extrusion dies in polymer processing is to obtain a uniform velocity distribution across the die exit .

Objective:

❖Develop an automatic optimization algorithm based on response surface method together with Kriging interpolation to optimize geometrical design of extrusion die to obtain a uniform velocity distribution across the die exit.

❖The extrusion simulations processed by using the REM3D® FEM software.

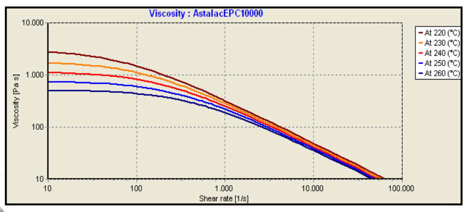


Fairly uniform exit velocity distribution

Viscosity model: Carreau Yasuda/WLF

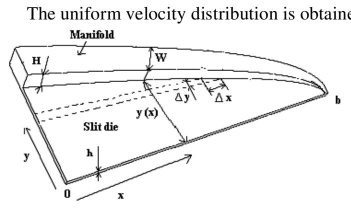
$$\eta = \eta_0 \left[1 + \left(\eta_0 \frac{\dot{\gamma}}{\tau_c} \right)^{a} \right]^{\frac{m-1}{a}}$$

$$\eta_0 = \eta_0(T_{ref}) \exp\left[\frac{A_1 (T_{ref} - T_s)}{A_2 + (T_{ref} - T_s)} - \frac{A_1 (T - T_s)}{A_2 + (T - T_s)} \right]$$



Design variables and objective functions:

The uniform velocity distribution is obtained by varying the f_p and a coefficients.

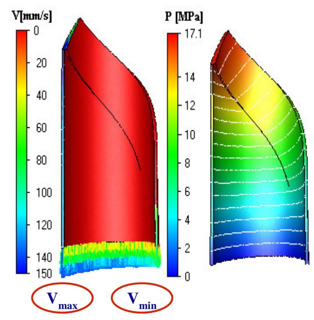


Sketch of coat hanger distribution system with wide manifold and narrow slit flow region.

$$H(x) = h\left[(b-x)/(a f_p h)\right]^{1/3}$$

$$W(x) = a\,H(x) = h\left[a^2 h^2 (b-x)/f_p\right]^{1/3}$$

$$0 \le f_p^{\,k} \le 1 \qquad 0.5 \le a^k \le 10$$



Objective function J

$$E = \left(\frac{1}{N} \sum_{i=1}^{N} \left(\frac{|v_i - \bar{v}|}{\bar{v}} \right)^2 \right) \qquad J = \frac{E}{E_0}$$

Constraint

$$G = \left(\frac{P - P_0}{P_0} \right)$$

The optimisation procedure

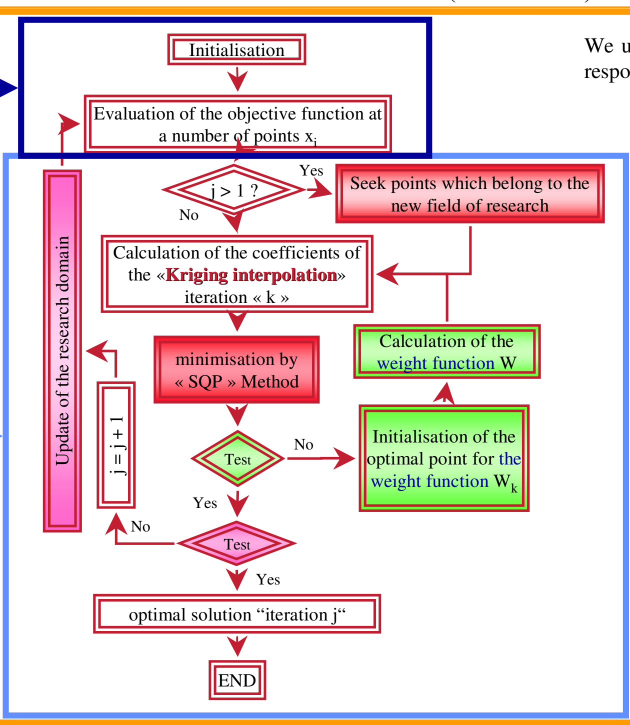
Routine for channel geometry change
Definition of die channel geometry

Trial Parameters

Pre-Processor GL-Pre
Operating conditions
Temperature of regulation, flow rate and rheological parameters of polymer melt.
& Mesh generation

Solver REM3D
Simulation of non-isothermal 3D flow

Optimization routine
Evaluation of the geometry



We use **Kriging** interpolations in order to approximate the response surface of the objective function.

$$\tilde{f}(x) = \sum_{i}^{m} p_i(x)\,\alpha_i(x) + \sum_{j}^{n} \beta_j\, g\left(\left|x - x^j\right|\right)$$

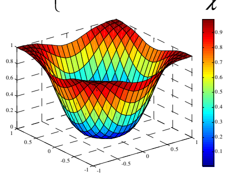
$$\alpha = (\hat{P}^T K^{-1} \hat{P})^{-1} \hat{P}^T K^{-1} F \qquad \beta = K^{-1}\left(F - \hat{P}^T \alpha\right)$$

$$K_{ij} = g\left(\left|x_i - x_j\right|\right) \qquad g(h) = h^2 \ln(h)$$

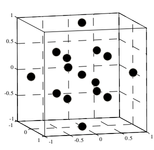
W is a weight function of the Gaussian type.

$$\begin{bmatrix} K + W & P \\ P^T & 0 \end{bmatrix} * \begin{bmatrix} \vec{\beta} \\ \vec{\alpha} \end{bmatrix} = \begin{bmatrix} \vec{f} \\ \vec{0} \end{bmatrix}$$

$$w_i(x,y) = \begin{cases} \left(1 - \dfrac{\exp(-(d_i/c)^2) - \exp(-(r/c)^2)}{1 - \exp(-(r/c)^2)}\right) * \chi & d_i \le r \\ \chi & d_i \ge r \end{cases}$$

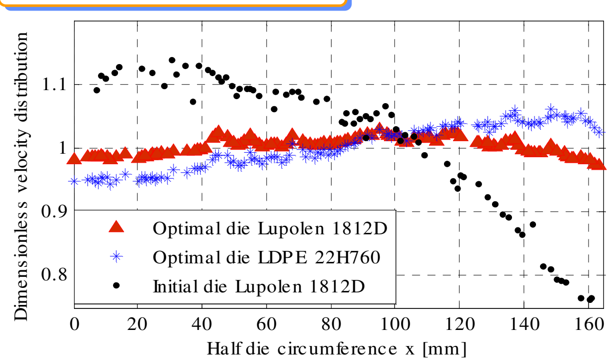


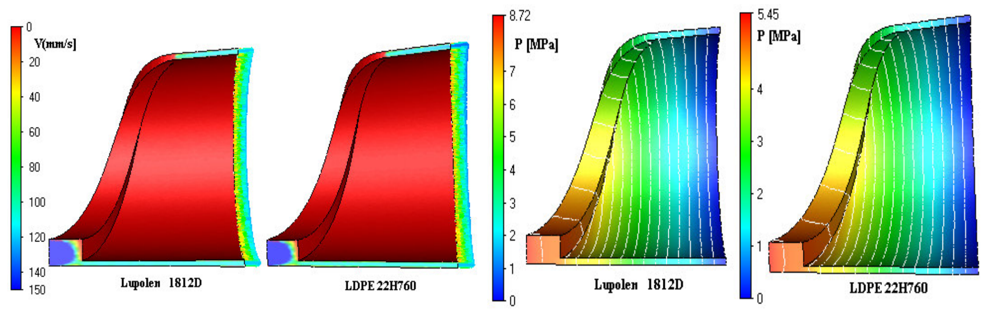
weight function of the Gaussian type



Design of experiment

Result of optimization





Velocity distribution and pressure in optimised die (B,C) for two polymer

Conclusions

riging method is more efficient (fast convergence).

he numerical algorithm presented in this work based on the global automatic optimization of extrusion die design shows promise as a tool capable of predicting optimal geometry and to have a design process less dependent on personal knowledge.

he optimal 3D die extrusion is a short length compared to the initial die and gives a good exit velocity

Future work

e consider to optimise the temperature of regulation instead of modifying the geometry while keeping the same objective function (velocity difference at die exit).

ptimise a die for different material range.