Computer Aided Design of Extrusion Dies for Profiles

J. M. Nóbrega, O. S. Carneiro, F. T. Pinho*, P. J. Oliveira**

Departamento de Engenharia de Polímeros, Universidade do Minho, Campus de Azurém, 4800-058 Guimarães, Portugal

* Departamento de Engenharia Mecânica e Gestão Industrial, Faculdade de Engenharia da Universidade do Porto, Rua Roberto Frias, 4200-465 Porto Codex, Portugal

** Departamento de Engenharia Electromecânica, Universidade da Beira Interior, Rua Marquês D´Ávila e Bolama, 6200 Covilhã, Portugal

1. Introduction

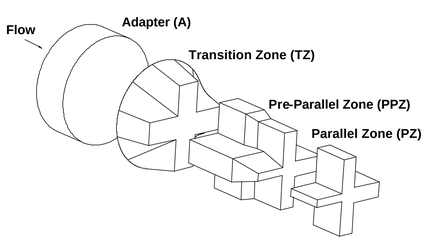
In this work a methodology to automatically balance the flow in profile extrusion dies is used. For this purpose a computational code, based on the finite-volume method, was developed and used to perform the required three-dimensional numerical simulations of the flow.

The methodology is illustrated using two case studies, each one leading to the adoption of a different constructive solution (with and without the inclusion of flow separators).

In order to evaluate the quality of the automatically generated die geometries, an objective function, that takes into account the flow balancing and the ratio L/t of the parallel zone, is proposed.

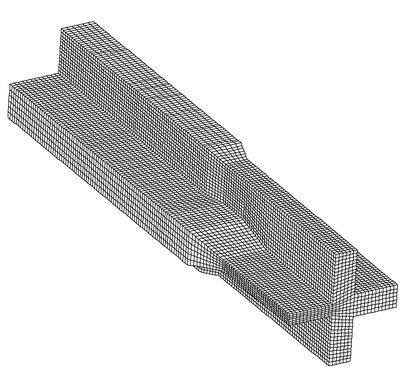
2. Methodology

- Division of die in four main zones, namely the die land or parallel zone (PZ), the pre-parallel zone (PPZ), the transition zone (TZ) and the adapter (A). The non-conventional PPZ was inserted between the TZ and the PZ, in order to facilitate the local control of the flow resistance without influencing the final extrudate dimensions.



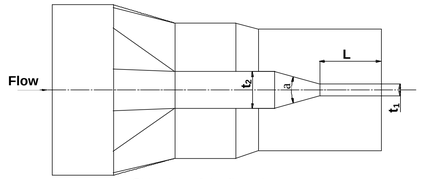
Flow channel of a profile extrusion die split in the main geometrical zones

- Perform the numerical modelling of the flow in the domain 'PZ+PPZ'.



Typical mesh used in the calculations

- Change PPZ geometry until flow balancing is reached.



Side view of the flow channel
PPZ geometrical controllable parameters

- Check the geometry in terms of practical feasibility. If the L(length)/t(thickness) ratio of the most restrictive sub-sections is lower than the advisable value, the process should be restarted using another constructive solution (inclusion of flow separators).

Objective function

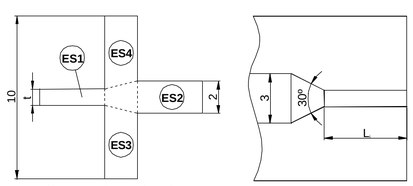
The value of the objective function decreases with increasing performance of the die, being zero for a balanced die having all the ES lengths in the admissible range.

$$F_{obj} = \sum_{i=1}^{4} \left\{ \alpha \left(1 - \frac{V_i}{V_{av}} \right)^2 + k(1-\alpha) \left[1 - \frac{(L/t)_i}{(L/t)_{opt}} \right]^2 \right\}$$

k=0 for $(L/t)_i \geq (L/t)_{opt}$ and $k = 1$ for $(L/t)_i < (L/t)_{opt}$,
V_{av}, V_i - average velocities of the extrudate and of the flow in each ES, respectively
$(L/t)_i$ - ratio between length and thickness of each ES
$(L/t)_{opt}$ - optimum value for the ratio L/t (=7)
α - relative weight (=0.75)

3. Case Study

Flow channel geometry

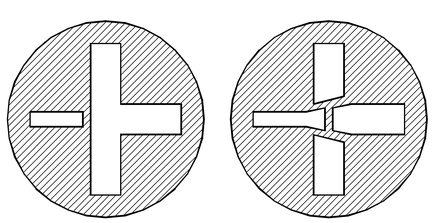


Cross section of the PZ
Elemental sections (ES) considered

Side view

	t [mm]	
CROSS-B	1.8	almost balanced
CROSS-U	1.5	strongly unbalanced

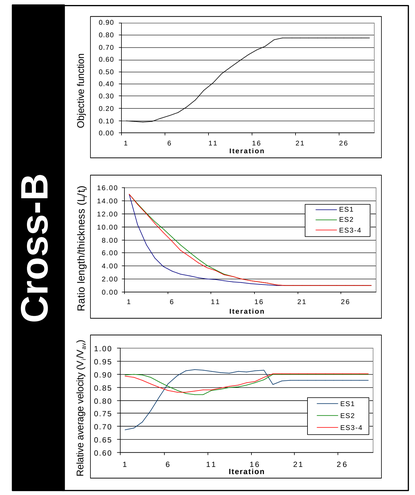
Inclusion of flow separators

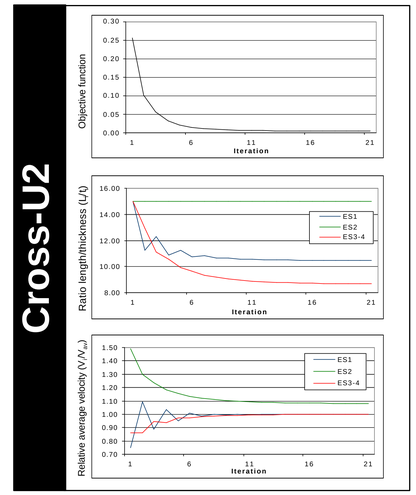


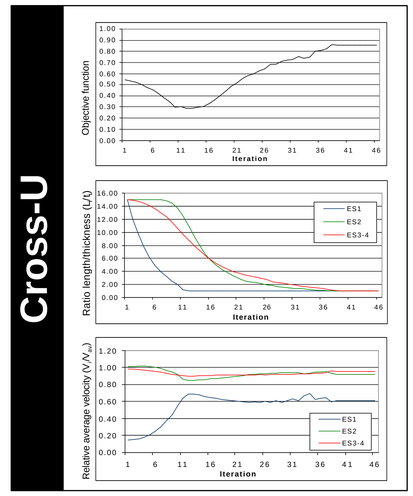
Cross-U1 Cross-U2

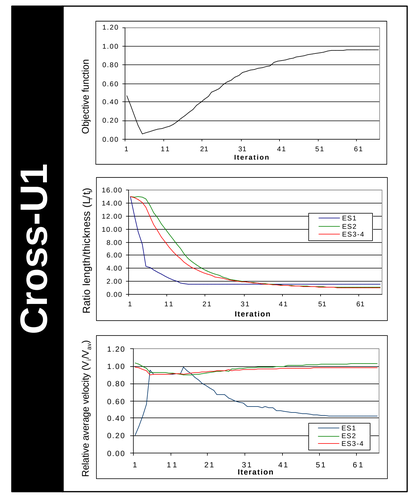
Cross section of the PPZ upstream of independent streams junction, showing the flow separators used

4. Results

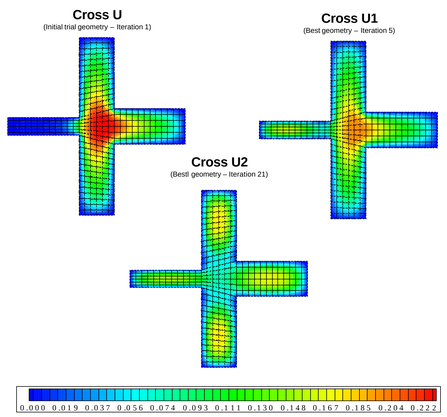








Velocity Field [m/s]



5. Conclusion

- In this work a methodology for the automatic flow balance of profile extrusion dies was tested.
- It was shown that the insertion of a pre-parallel zone facilitates the search of a flow balanced geometry.
- The objective function used has shown to be adequate to evaluate the performance of the extrusion dies used in this work.
- The insertion of flow separators was shown to be a good solution in terms of flow balancing, but it must be well pondered in order to minimise the risk of mechanical failure of the extrudate.