AUTOMATIC DESIGN OF PROFILE EXTRUSION DIES: EXPERIMENTAL ASSESSMENT

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INTRODUCTION

There are two main issues to solve when designing a profile extrusion die, the flow distribution and the post-extrusion effects, being the first the one that most influences the die performance [1-4]. Due to the large amount of variables involved and to the geometrical complexity of a typical extrusion die flow channel, especially in the case of complex cross-section geometries having different local flow restrictions, the design of these tools is usually based on trial-and-error procedures, that can be performed either on an exclusively experimental basis or on a combination of experimental and numerical work. In any case, the methodology used is very time consuming and relies essentially on the designer's experience, since the decisions necessarily involved in this process are always committed to the designer [3].

In order to minimise the before mentioned difficulties a die design code is being developed, being its main purpose to carry out the automatic search of an optimised geometry [5]. The code consists of an optimisation routine coupled with geometry and mesh generators and 3D computational routines based on the finite volume method, able to predict the complex flow patterns involved and the corresponding local fluid temperature variations promoted by viscous heat dissipation and/or specific thermal boundary conditions. Different design strategies were implemented [6], namely those encompassing the search of the best set of flow channel lengths (strategy 1, ST1) or the best set of flow channel thicknesses (strategy 2, ST2) of the extrusion die final parallel zone in order to obtain in each elemental section a local average velocity equal to the average velocity of the profile or to obtain local flow rates that allow the attainment of the required thickness after draw-down (pulling promoted by the haul-off unit), respectively.

In this work the developed die design code is used to optimise the flow channel of a specific extrusion die. The numerical results obtained are compared with experimental data gathered during extrusion experiments. This set of experiments enabled to assess the rheological code and the effectiveness of the optimisation algorithm and design strategies implemented.

FLOW CHANNEL OPTIMISATION

The final region of the extrusion die flow channel under investigation is depicted in Figure 1 and its dimensions are shown in Table 1. The different thicknesses specified, ranging from 2 mm to 4 mm, were deliberately imposed in order to promote different local flow restrictions.

The geometry of the flow channel was optimised using the methodology described in [5] considering two different approaches: one using length optimisation (ST1) and other using thickness optimisation (ST2). The dimensions of the extrusion die flow channel, for the initial trial and for the optimised geometries are shown in Table 1.

EXPERIMENTAL ASSESSMENT

For assessment purposes, three modular instrumented extrusion dies were designed and machined: one using the same ratio length/thickness for all elemental sections (INI – Initial trial of the optimisation algorithm) and two corresponding to the two optimised geometries (ST1 and ST2). Extrusion experiments were carried out using a polypropylene extrusion grade under several different operating conditions (throughput and die temperature), including those used during the design stage. The flow distribution predicted by the software was assessed through comparison of the predicted and measured relative areas of the different elemental sections considered for optimisation purposes, using a methodology similar to the one proposed by [3]. These data are shown in Table 2. The performance enhancement obtained by applying the optimisation algorithm is evidenced in Figure 2.

CONCLUSIONS

In this work a methodology previously developed to carry out the automatic optimisation of profile extrusion dies was assessed. The results obtained allow concluding that the numerical predictions are reasonably accurate and that the optimisation methodology developed is a valuable step towards the automatic die design concept.

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Table 1 – Dimensions of the extrusion die flow channel for the initial trial (INI) and for both optimisations performed (ST1 and ST2).

	INI		ST1		ST2	
	L	t	L	t	L	t
ES1	30.00	2.00	7.50	2.00	30.00	2.41
ES2	37.50	2.50	11.50	2.50	37.50	2.72
ES3	37.50	2.50	11.50	2.50	37.50	2.72
ES4	45.00	3.00	17.50	3.00	45.00	2.96
ES5	30.00	2.00	7.00	2.00	30.00	2.49
ES6	60.00	4.00	60.00	4.00	60.00	3.24

(dimensions in mm)

Table 2 – Relative elemental cross-section areas (experimental and numerical results).

		ES1	ES2+3	ES4	ES5	ES6
INI	**E**	3.3%	17.9%	18.8%	7.2%	52.9%
	N	2.9%	16.3%	19.2%	6.7%	55.0%
ST1	**E**	8.5%	26.5%	18.0%	17.6%	29.4%
	N	8.2%	25.4%	19.1%	18.9%	28.4%
ST2	**E**	7.5%	26.3%	20.2%	20.6%	25.5%
	N	7.4%	25.8%	19.7%	20.3%	26.8%

E- Experimental / **N** - Numerical

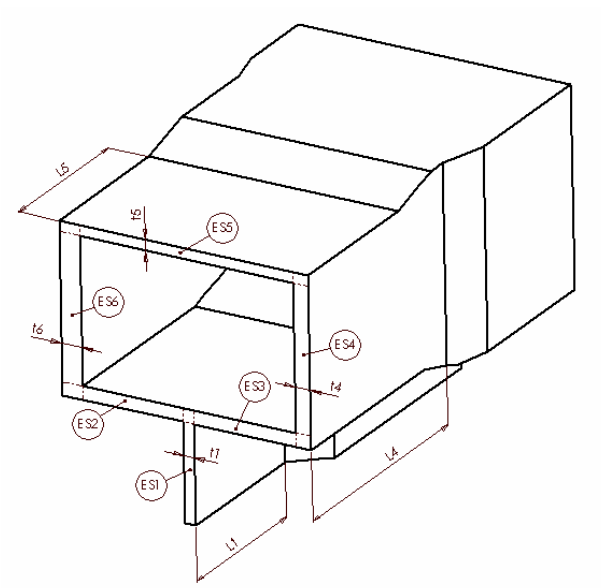
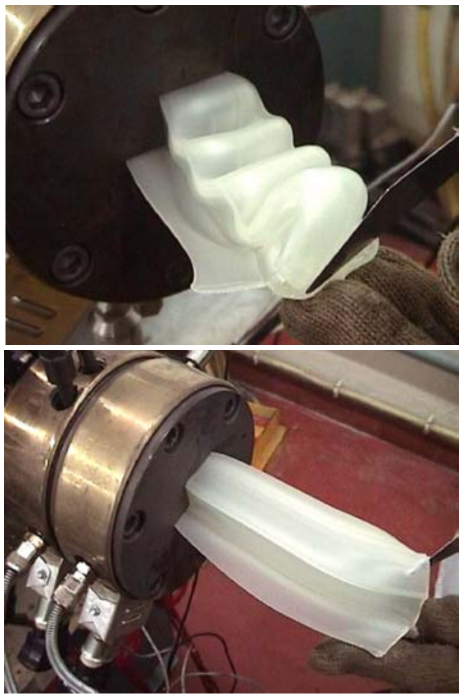


Figure 1 – Geometry of the final region of the extrusion die flow channel



(a)

(b)

Figure 2 – Flow at the die exit: (a) initial trial die; (b) optimised die (ST1).