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Innovative approach to the design of profile extrusion dies

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Investigation of an extrusion die designed for the production of wood-plastic-composite decking profiles shows that numerical tools help to optimize flow balance.

Today, due to the continual emergence of new and sophisticated products, profile extrusion faces new challenges that are motivating the adoption of innovative design methods. The major problem in designing a profile extrusion die (typically used, for example, in manufacturing decking, medical catheters, and electronics) is how to achieve an even flow distribution owing to the complex rheology of the materials employed and the intricate, sometimes counterintuitive flow phenomena occurring inside the flow channels. The traditional trial-and-error approaches usually employed in the design of profile extrusion dies require highly skilled designers whose success depends heavily on their experience. In the absence of any previous practice with similar products, these approaches may involve many trials and do not guarantee satisfactory results. Consequently, traditional die design methods consume resources (time, material, and money) and thus are ill suited to a highly competitive context.

The use of numerical tools to model the flow inside the die flow channel, and to analyze the effect of geometric modifications on the flow distribution, may help to conserve precious resources.[1,2] However, even when numerical tools are brought to bear, the major decisions required to obtain an improved flow channel are still made by the designer. Minimizing dependence on the designer requires fully automatic design schemes in which optimization software makes the most important process decisions and corrects the geometry without any user intervention. Such design of profile extrusion dies is still in its infancy stages. Software that developed so far is able to tackle only simple geometries[3] or must assume 2D simplified versions of the 3D flow inside the channel.[4] Here, we describe work[2] that exemplifies the use of numerical modeling software in the design of an extrusion die to produce the WPC (wood-plastic-composite) decking profile shown in Figure 1. The WPC material comprises 50wt% of wood particles in a poly(vinyl chloride) (PVC, K57) matrix.

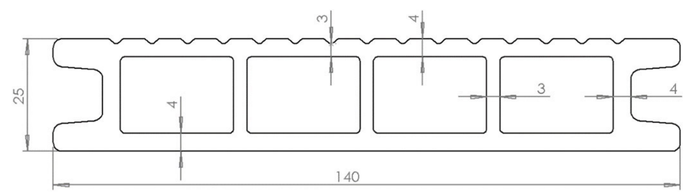

Figure 1. *Wood-plastic-composite (WPC) profile cross section (dimensions in millimeters) of a decking profile.*

Figure 2. *Typical mesh employed in the modeling calculations (for reasons of symmetry, only half of the geometry was considered).*

We used a rheometer to characterize the properties of the material and then adjusted the resulting data using the so-called Bird-Carreau function. An advantage of our numerical modeling software[1] is that it can handle unstructured meshes—i.e., complex geometries—such as triangles, prisms, and tetrahedrons. Structured meshes, in contrast, are based on simple elements like squares and cubes for which complex geometries pose a challenge. Figure 2 shows a typical mesh employed in all our calculations.

Throughout the optimization process, we modified the extrusion die flow channel in order to improve the flow distribution (see Figure 3). The figure shows adjustments to thickness based on the results of successive simulations. To assess the predictions made by the software,

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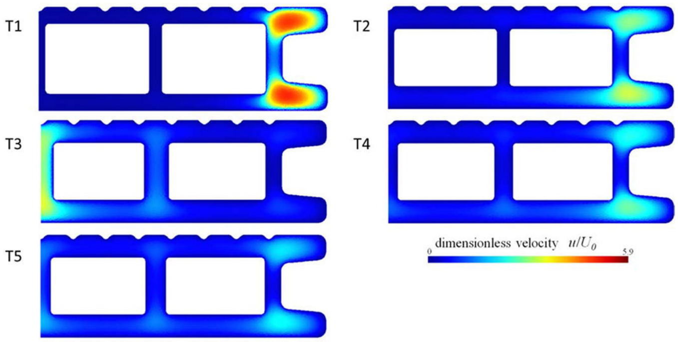

Figure 3. *Evolution of the velocity distribution at the flow channel outlet throughout the optimization process.* U_0 *is the cross-section average velocity. T1 to T5 represent levels of optimization from initial to optimized trial geometry.*

Figure 4. *Profiles produced during the experimental runs.*

we machined the initial and final optimization process geometries and tested them experimentally. Figure 4 shows the profiles produced using both extrusion dies. The improvements obtained are obvious. For example, the first die—see Figure 4(a)—failed to produce a profile with a constant cross section, whereas the final trial—see Figure 4(b)—produced both the desired cross section and the required dimensions.

The results we have presented provide a clear illustration of the advantages of employing software to aid the design of profile extrusion dies: the rheological software successfully predicted the flow distribution. The alternative is the experimental approach, requiring the production of several extrusion dies with significant time and material consumption. Currently, our University of Minho research team, which carried out this work, is advancing automatic design methods for extrusion dies by developing numerical modeling software able to deal with even more complex geometries,[1,5] and similar tools to aid the design of profile calibration and cooling systems.

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