# Design and Production of Injection Molding Tools for IXEF® Polyarylamide Compounds

IXEF compounds are highly filled semi-aromatic nylons that exhibit remarkable strength and stiffness. The high fluidity of the base polymer ensures good flow, even with a glass fiber content as high as 60%. This makes it easy to fill very thin sections—approximately 0.5 mm (20 mils), even 0.3 mm (12 mils) locally—and to precision mold complex parts. The material's high flow also provides a defect-free surface with no visible surface fibers.

Due to the unique nature of IXEF compounds, it is important to properly design and fabricate the tools used for injection molding. From the early stages of product design, you should begin thinking about the best way to build the mold to optimize its performance and eliminate costly, time-consuming changes during production.

To help you with this, we have provided information in this bulletin that is specific to IXEF compounds for the following mold-making steps:

- part design
- mold definition
- detailed drawing and production of the mold
- cutting steel
- assembly and testing
- polishing and surface treatments

## STEP 1: PART DESIGN

To optimize performance, you must consider a number of mechanical, dimensional and visual parameters.

### A. Mechanical Properties

***Radii***

Internal corners with sharp angles or very short radii, as well as notches, are one of the main causes of part failure under load. If possible, the radii should be 0.6 mm (24 mils) or more to help prevent stress concentration in both the part and the mold. Smooth corners also decrease tool wear and make it easier to eject the part from the mold.

***Draft Angles***

Draft angles must be included in the design. They should be a minimum of 1° for a polished surface (Ra < 0.5k VDI 14) and up to 3° for a textured surface (Ra < 4.5, VDI 33).

***Weld Lines***

Weld lines are weak areas formed by converging flows of plastic that can lead to mechanical part failure if not properly accounted for in the part design. With IXEF compounds, the strength of a weld line is typically 90 MPa (13,000 psi).

***Gate Design***

The optimum gate design will minimize the flow distance of the molten plastic in the cavity, reduce weld line problems in the part, and minimize the effects of fiber orientation and melt turbulence. Design variables to consider include number of gates, their size and shape, and their location.

As a general guideline, the gate land length should be between 0.8–1.6 mm (30–60 mils). In order to properly pack the part, the smallest gate dimension should be at least 50% of the part wall thickness and the gate should be located at the thickest section of the part. Corners should be radiused generously to reduce shear. For applications where fast fill rates and good part aesthetics are required, avoid gate locations and designs that result in melt turbulence.

Sub-gate diameters (d) for IXEF compounds are dependent on the wall thickness (w) of the molded part. If the gate is too small, glass-fiber content can be reduced in some areas of the molded part. For cold gates, we suggest the following guidelines:

- d = w for a direct feed
- d = 2w for a thin part (min. thickness of 0.8 mm (30 mils))

### B. Critical Dimensions

***Shrinkage***

IXEF compounds are characterized by low shrinkage during molding. Actual shrinkage depends on the IXEF grade used as well as the geometry of the part (most notably the thickness), position of the gates, and packing during cooling. Guidelines for thin-wall sections (<2 mm (80 mils)) are shown below in Table 1.

Table 1

**Shrinkage guidelines for thin-wall applications**

| Grade | Glass Content | Average Shrinkage |
|---|---|---|
| IXEF 1032 | 60% | 0.20% |
| IXEF 1022 | 50% | 0.20% |
| IXEF 1002 | 30% | 0.25% |

*Tolerances*

Because the shrinkage for IXEF compounds is very low, molders can typically achieve tolerances in the range of ±0.05%.

### C. Visual Considerations

You must carefully position the gate, ejectors, split (parting) lines and movements to avoid potential flash and venting problems.

*Sink marks*

Very thick sections in a molded component typically cause sink marks. The high fluidity and low shrinkage of IXEF compounds help minimize their occurrence. For example, a local thickness can be up to five times thicker than the rest of the part without sink marks appearing.

### D. Software for tooling and mold simulation

Our technical support team uses the full range of Moldflow® software (Midplane, Fusion and 3D) to help optimize tool design. The most appropriate mesh option is chosen to get fast and reliable answers. FLOW-3D® now has fiber and warpage capabilities and is likely to become the preferred tool. The advantage is the fast conversion from CAD (step, iges, stl ) to tetrahedral mesh. The downside is the relatively long computing time, which can take several days.

## STEP 2: MOLD DEFINITION

At this step, the mold maker must determine the number of cavities, type of steel, use of a hot runner, position and number of ejectors and vents, cooling channels, and a number of other basic tooling parameters.

Because it is easier to remove steel from a tool than to add steel to it, you should consider steel safe solutions first, then make adjustments as needed.

*Type of Steel*

The steel used for molding tool must be hard enough to withstand the abrasive nature of a glass-filled material. For IXEF compounds, we recommend a hardness of at least 54 HRc for the cavity steel. Other factors such as the ability to mill and polish the steel plus the material's brittleness and thermal conductivity must also be considered. Commonly used mold steels include STAVAX ESR, ORVAR SUPREME and ELMAX from Uddelholm. Table 2 lists standard equivalents for a number of other steel types.

Table 2

**Standard equivalents for various types of steel**

| DIN | WNr | AFNOR | AISI |
|---|---|---|---|
| X42Cr13 | 1.2083 | Z40C14 | 420 |
| X36CrMo17 | 1.2316 | Z40CD16 | |
| X155CrMoV12.1 | 1.2379 | Z160CDV12 | D2 |
| X210Cr12 | 1.2080 | Z200C12 | D3 |
| X40CrMoV5.1 | 1.2344 | Z40CD5 | H13 |
| – | – | X50CrMoWV5 | – |
| – | 1.3543 | X105CrMo17 | 440C |

*Clamping force*

The tool must be rigid enough to handle the high clamping force needed to accommodate high injection pressures and the high fluidity of the polymer. In general, its best to use the formula: clamping force needed per projected surface area equals 1Ton/cm$^2$ or 7.1Ton/in$^2$.

*Venting and flash*

Because IXEF compounds are highly fluid, caution must be taken when venting the mold to prevent the risk of flash. Venting is preferable in non-visual areas and should be as wide as possible with a thickness up to 0.01 mm (0.4 mils).

*Heating and cooling the mold*

Since IXEF compounds require a mold temperature of at least 120°C (248°F), the mold must have enough cooling channels and fixtures to operate at this temperature. We recommend cooling channels with a 10-mm (0.4-in.) diameter. In order to keep a constant cavity surface temperature +/- 5°C (9°F), cooling channels should be uniformly located 15 mm (0.6 in.) from the mold cavity and 20 mm (0.8 in.) from each other as measured from the center of the channel. The mold also needs insulation plates to help reduce heat loss.

*Hot runners*

IXEF compounds can be used with hot runners which offer savings in both material and energy. We recommend Moldmaster, Husky, Incoe and Eurotool among others.

## STEP 3: DETAILED DRAWINGS AND PRODUCTION OF THE MOLD

The mold-maker is primarily responsible for this work. It should include ordering parts, reserving machining equipment, and heat-treating the cavities.

## STEP 4: CUTTING STEEL

After the steel is milled, it must be heat treated and quenched in order to achieve the appropriate hardness. Because steel can deform during the heat treatment process, it is important to allow for this in a steel safe manner. After heat treatment, final operations such as milling, electro-erosion and wire cutting can take place.

For electro-erosion, it is especially important to consider any heat-affected zones. During heat treatment, a fine layer of highly oxidized steel is formed which is very brittle. If this layer is not removed from these areas by sand blasting, it will eventually break off and cause problems during injection molding.

## STEP 5: ASSEMBLY AND TESTING

Once all of the components are ready, the tool should be assembled and adjusted to verify that it operates correctly.

Before the tool is sent to the injection molder, there are still a few checks that need to be done to ensure the quality of the tool. The two most important points are blue-printing (known as red-printing in Asia) and ease of use.

### *Blue-printing*

Blue-printing is done on an injection molding machine at 15% of the clamping force. It is critical that this is done before the tool is sent to the injection molder to ensure that the split line is correct and to prevent flash during production.

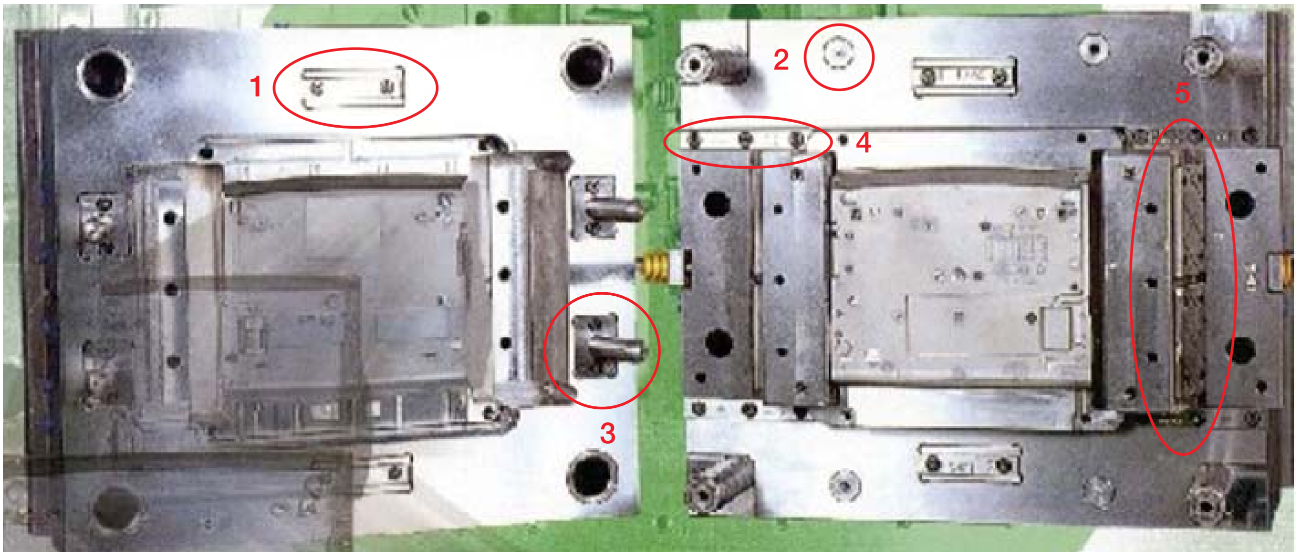
### *Ease of Use*

Check the ease of assembly, maintenance and repair. Key areas are outlined below and are in reference to Figure 1.

1. Mold centering adjuster – ensures that both fixed and moving parts of the tool are correctly aligned
2. Ejector return pin – ensures that the ejector plate is set back to the correct position prior to the next molding cycle
3. Replaceable angle pins – can be easily removed, replaced or adjusted using a simple screw assembly
4. Replaceable side cores – can be easily removed using the screws that are noted
5. Adjustable wear plates – front-mounted wear plates can be easily removed and adjusted to optimize split line and prevent flash due to tool wearing.

Figure 1

**Example of mold with easy assembly and maintenance features**



## STEP 6: POLISHING AND SURFACE TREATMENTS

We recommend polishing the tool as it serves two purposes that relate to the material's ability to reproduce fine detail in the mold. First, if there are rough areas left from machining, electro-erosion or wire cutting, there may be a tendency for the part to stick during ejection. Second, the part may need a high polishing on the mold for aesthetic reasons.

Because IXEF compounds contain a high level of reinforcement, surface treatments can be added to the mold once the parts have been approved to increase the life of the mold. Specialists in these types of coatings include Balzers, Bodycote, and Vide Express.

## CLOSING REMARKS

When designing and producing injection molding tools, it is important to accommodate the characteristics of the material you are using. For IXEF compounds, high flow and high filler content are the key factors that must be taken into consideration. For more detailed information on any of the topics covered in this bulletin or other technical issues related to IXEF compounds, please contact your Solvay Advanced Polymers representative.

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