Die Starter: A New System to Manage Early Feasibility in Sheet Metal Forming

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Abstract

Die Starter, a new system developed by ESI Group, allows the user to drastically reduce the number of iterations during the early tool process feasibility. This innovative system automatically designs the first quick die face, generating binder and addendum surfaces (NURBS surfaces) by taking account the full die process. Die Starter also improves the initial die face based on feasibility criteria (avoiding splits, wrinkles) by automatically generating the geometrical modifications of the binder and addendum and the bead restraining forces with minimal material usage.

This paper presents a description of the new system and the methodology of Die Starter. Some industrial examples are presented from the part geometry to final die face including automatic developed flanges, part on binder and inner binder.

Introduction

Today, sheet metal forming simulation is completely integrated into the core business of die engineering of OEM and suppliers, from early feasibility assessment and initial cost estimation to virtual try-out and final inspection. For example, the combination of ESI’s Visual DIEMAKER (VDM) or CATIA DIEMAKER with PAM-STAMP provide a powerful toolset capable of working through the entire process, from tipping, part preparation, binder, addendum and analysis to trimming and flanging.

Despite the progress, early tooling feasibility process still requires multiple iterations. The modifications are based on trial and error and require skilled users. Even if best practices for die face have been integrated into die design strategies, there remain issues including:

- Die face design will vary, depending on the user
- Die face design is not necessarily optimal for a given set of requirements and constraints
- Creation of an acceptable die face solution is simply too slow, especially for complex parts.

Accordingly, there is clearly a demand for a robust, repeatable and streamlined die face engineering process that addresses early stage of feasibility assessment, when effective product design decisions must be made. Furthermore there is a critical need to greatly shorten the cycle time between part design and early tooling feasibility.

For those reasons a new approach has been proposed and developed by ESI Group and is now industrialized as a new solution, Die Starter. This new software module enables engineers to manage early feasibility in sheet metal forming by automatically generating, from minimal input parameters, a quick die face design (also known as “initial die face”), defining binder and addendum surfaces (NURBS surfaces). Based on the use of parametric geometry, modifications and improvements of initial die face can be performed quickly and automatically using a mathematical optimization algorithm procedure.

Die Starter Workflow

Die Starter is completely integrated into ESI Visual DIEMAKER (VDM, on ESI’s Visual Platform) and ESI CATIA DIEMAKER (CDM, on Dassault Systèmes, CATIA V5 platform), and provides solutions for early up-front feasibility assessment.

Before running Die Starter, the part must be prepared and those steps are:

- Part and mode definition (symmetry, flanges selection...); Tipping position
- Prepare the part to achieve a defined part outline (fill holes, rolling cylinder only if required)
Executing Die Starter for a quick die face design automatically generates the following output:
- Binder and addendum surfaces (outer and inner binder); Bead center lines and blank outline (IGES format)
- Analysis results, including thinning and strains for design check

In order to improve the initial die face geometry, a mathematical optimization technique is used. Different types of optimization are offered, specific to the binder, addendum surfaces or bead restraining forces. Performed automatically, Die Starter optimization generates the same types of data as for the initial die face step. Figure 1 illustrates the Die Starter process applied for a door inner. Once the full die face is created from Die Starter, process information and geometrical results, including draw beads restraining forces are exported to PAM-STAMP via a Quick-Link to achieve nearly automatic simulation set-up and analysis. The user can also modify or redesign their own die face based on Die Starter geometry by using Visual DIEMAKER functions. Finally, Die Starter results can be exported to any CAD system (CATIA, Unigraphics, SolidWorks…) for manual modifications.

![Die Starter process steps](image)

(a) Part geometry, (b) Die Starter part preparation (fill holes, smooth part outline)

(c) Die Starter input deck and initial die face solution, (d) Improved die face after die starter optimization (binder – bead – addendum); (e) PAM-STAMP Analysis from die starter optimization results after few manual improvements.

**Figure 1:** Door Inner: Die Starter full process steps: (a), (b) part preparation, (c) initial die face solution, (d) final die face solution from optimization and (e) PAM-STAMP results after few manual improvements from optimized solution

**Die Starter Benefit and Capabilities**

The main characteristics of Die Starter are automatic initial die face then optimization and bead optimization on customized die face.

**Characteristics: Customized die face:**

Based on the entire die face geometry (part, binder and addendum surfaces), Die Starter will perform a quick formability analysis on the full die face and then bead optimization will provide optimum bead restraining forces (also segmentation) for improved formability.

**Characteristics: Automatic initial die face:**

Based on minimal part preparation, Die Starter provides within a few minutes a complete die face design that is usually acceptable and accurate. The automatic initial design is based only on geometrical and process criteria. The different characteristics are:

- Binder surfaces (NURBS surfaces) based on developable /wrappable binder criteria in most cases, including part on binder and inner binders. The binder orientation is also defined automatically. Specific double curvature binder, imposed flat binder and non-developable binder are also available.
- Addendum surfaces (NURBS surfaces) are a combination of the two principal profile concepts (standard addendum and step/bar addendum) which represent the majority of parts. An automatic global smoothing technique is used to provide clean and smooth punch and die opening lines; both critical in die face design principles. Inner addendum surfaces are also defined.

- A quick formability analysis [1-2] is automatically performed just after an initial die face design, in order to provide an estimation of the feasibility of the draw-part. This first feasibility assessment can guide the next steps, such as a direct PAM-STAMP analysis if the part appears feasible or Die-Starter optimization if thinning (high or low) needs to be corrected.

Characteristics: Automatic Optimization:
Built on a parametric surfaces engine, Die Starter has the capability to automatically modify or redefine the tooling geometry during optimization steps. The optimization uses a mathematical optimization algorithm [3-4] combined with a formability analysis and a defined objective function with or without constraints (geometrical and mechanical).

The use of fast feasibility allows the optimization of both tooling geometry and process parameters in order to deliver at an early stage a feasible part with a stable and robust press tool process. The different optimization options are:

- Binder optimization
- Addendum optimization: Punch radius and wall addendum for type 1; Draw bar creation, punch radius and wall addendum for type 2 (type 1 and 2 are also available for inner addendum)
- Draw beads sections with associated restraining forces (also available for customized die face process)
- All of the above, individually and in combination (and all combinations between them)

Capabilities:
- Develop flanges into addendum (also binder) automatically
- Define binder and addendum (outer/inner) surfaces automatically (initial and optimization)
- Develop automatically part on binder
- Handle symmetric parts: create complete symmetrical die face (initial and optimization)
- Provide good surface quality for binder and addendum automatically. At this stage of the process, this is very important and can have a significant impact on time for creating the final die design in CAD system.
- Only few input parameters are required, related to material, process and optimization target
- A first initial die face and design check is completed in a few minutes, an optimization of an early design in few hours calculation time. Minimal human intervention is required during the Die Starter process.
- Perform quick feasibility analysis and bead optimization on a pre-defined die face
- Die face geometry (initial and optimized) from Die Starter can be loaded into any CAD system
- Die face and addendum profiles can be imported into VDM for manual modifications

Industrial Examples
This section shows some examples that ran in Die Starter for initial die face and optimization. Figure 2 shows 3 different parts that ran for initial die face. The first example (a) is a full die face of a liftgate outer with inner binder/addendum. The second example (b) is an s-rail die face with part on binder, and the third example (c) is a fully symmetrical initial die face of a hood inner calculated with a double curved binder (material saving).

Figure 2: Examples of Die Starter: (a) Liftgate outer with inner binder and addendum. (b) S-rail initial die face with part contour on binder. (c) Hood inner fully symmetrical die face with double curved binder
Figure 3 is the initial die face of a fender outer with automatic development of flanges into the addendum (direct trimmed line from developed flange outline).

![Figure 3](image)

**Figure 3**: Die Starter fender initial die face with developed flanges: (a) fender part with flanges; (c), (d) initial die face with automatic developed flanges into addendum (developed trim line in orange)

The last example (figure 4) is a hood inner panel, performed for initial and optimized die face. During optimization, the rear corner areas of the addendum have automatically been changed in order to meet the maximum thinning requirement (no split after optimization). After running a validation analysis (PAM-STAMP) using the optimized die face, the feasibility of the panel is good.

![Figure 4](image)

**Figure 4**: Die Starter hood inner (rear corner): (a) Initial die face and (b) optimized die face, with (c), (d) thinning results comparison in PAM-STAMP

**Conclusions**

ESI Die Starter, a new solution module integrated into Visual DIEMAKER (built on ESI Group’s Visual Platform) and CATIA DIEMAKER, has been presented in this paper. For the early stage of tool feasibility in sheet metal forming, Die Starter automatically generates a complete die face including binder and addendum surfaces, bead center lines and restraining forces associated for a prepared part. An initial (quick) die face can be created in a few minutes. A mathematical optimization method automatically modifies the initial die face in order to meet the formability specifications and requirements for minimum material usage. Die Starter solutions can be further modified in any CAD system or processed through Visual DIEMAKER/CATIA DIEMAKER to PAM-STAMP, if required.

**References**

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