Butterfly Dies - Increase Extrusion Speed through Innovative Porthole Die Design

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The Butterfly Construction consists mainly of designing the mandrel section of a porthole aluminium extrusion die giving the bridges an arched shape.
With this innovative architecture, the details in the undercut can be brought together by opening the external feeds and better supporting the difference in the flows called by the profile, thus achieving important results in terms of productivity and behavior of the porthole die during extrusion.
A case study has been used to compare the behavior of a Butterfly Die™ with the one of a traditional Porthole die design. 3D FEM simulation will be used to develop the Butterfly Die™ in terms of feeding balance trough multiple ports.

INTRODUCTION

The Butterfly Construction was introduced in Italy at the end of the 90's thanks to the cooperation between Alcoa Fossanova and Claudio Pinter, former General Manager of Alcoa Trasformazioni, now Almax-Mori Srl, the company that, since 1965, has always been in the vanguard of the design and construction of aluminium extrusion dies.

Initially apprehensive on the behaviour at the press of this new die design, the technical and sales divisions of Almax-Mori had to reconsider their views when observing the growing interest of Italian customers and competitors towards the Butterfly Die™.

Today Almax-Mori applies this new construction to an average 25% of the dies produced per year, and figures show a significant increase in the request of this design by Italian and International customers.

A fruitful partnership with the customers is the basis of the continuous improvement of the Butterfly Die™, allowing Almax-Mori to apply it to a wide range of profile shapes and dimensions.

BENEFITS OF THE BUTTERFLY DIE™

By positioning the bridges in the right way, the details in the undercut can be brought together by opening the external feeds and better supporting the difference in the flows called by the profile, thus improving the supply to the exteriors and the concealed parts and achieving important results in terms of the behaviour of the die and the flow of aluminium during extrusion.

The use of a Butterfly Die™ in extruding aluminium profiles provides an important series of benefits. We can list a few of them, which European extruders referred as the most significant results achieved in their production process:

- better support against flexion of the mandrels;
- reduction of elastic failures of the cores;
- less impact pressure with the billet;
- reduced values of temperature and working pressure;
- increase of the extrusion speed up to 50% and therefore higher press productivity rates.

The excellent architecture of the Butterfly Die™ is suitable for use in place of the common 4 bridge one and can be easily processed with CAM systems, obtaining a finishing quality that it is very difficult to achieve with traditional architectures.

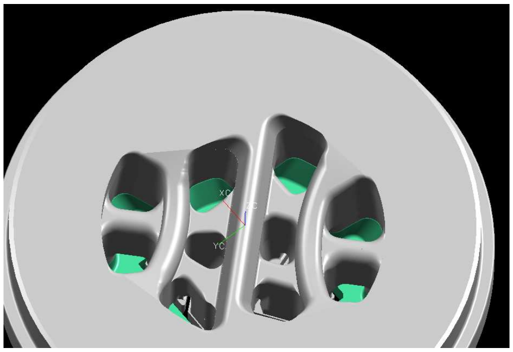

Figure 1: 3D CAD of a Butterfly Die™.

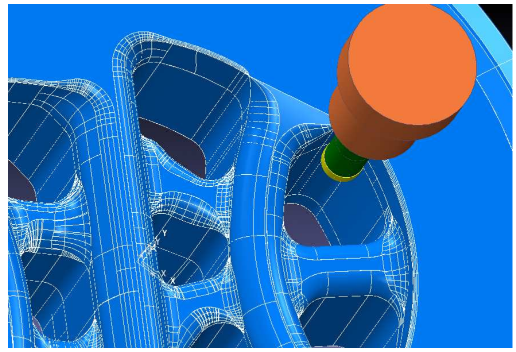

Figure 2: 3D CAM of a Butterfly Die™.

CASE STUDY

In the schematic graph below, the typical behaviour of a Butterfly Die in terms of working pressure of the press is compared with the one of a standard construction for the same profile geometry. Official production data are not available and a quantitative analysis of results achieved con not be given.

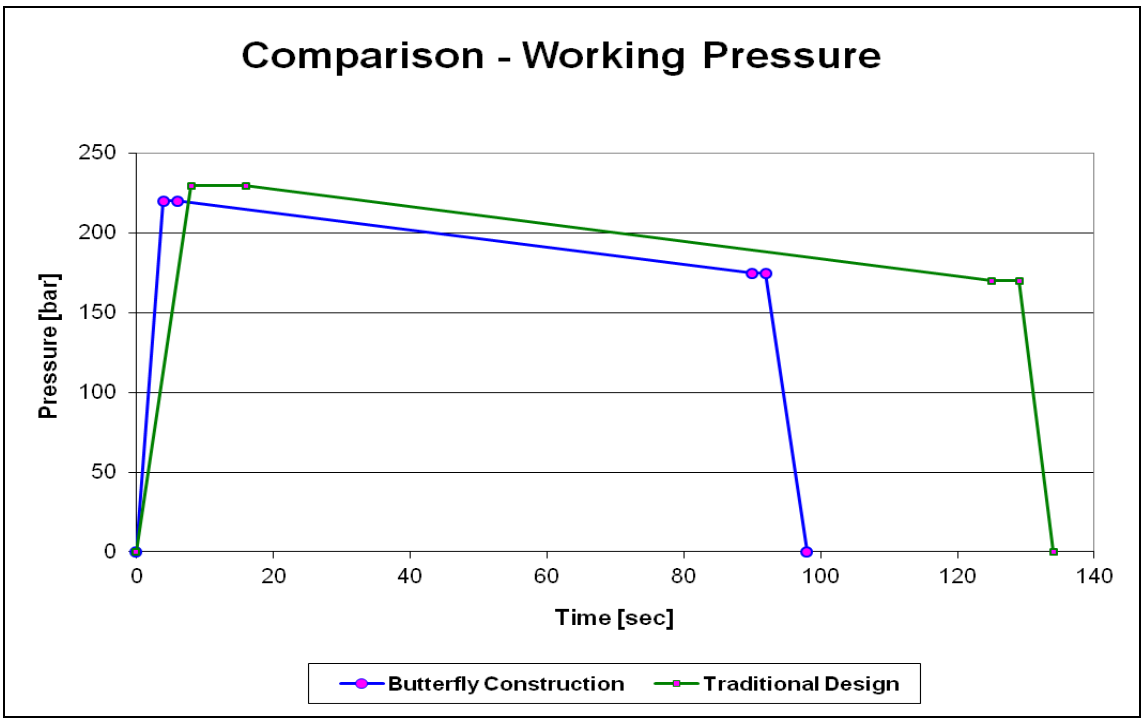

Figure 3: Schematic representation of a single extrusion run in terms of press working pressure (Measured Values) for the same aluminium alloy profile (2000t press).

As shown by the blue line, on the same direct extrusion press the Butterfly Die™ is easily feeded by the aluminium alloy. In this way we can reduce the total stress supported by the porthole structure achieving a friction reduction and a consistent increase of productivity. The difference in time on the single extrusion run shown in Figure 3 is due to the higher extrusion speed for the same initial pressure.

FEATURES AND APPLICATIONS

In recent years, the project has been the object of various improvements which have enabled it to be applied to a wide range of profiles shapes and dimensions.

Figure 4 shows the typical appearance of single cavity porthole die with Butterfly Construction. The remarkable lead-in holes are bigger than the ones of a standard design and thanks to the gap between webs it's possible to increase the call of aluminium. In this way the total friction is reduced by sliding of aluminium against aluminium.

The rounded bridges are lowered in the centre to reduce the impact pressure and help the alloy to get into the central feedings. In this way the most concealed parts of the profile are better feeded and the final result is higher productivity.

Figures 4 and 5 show the development of the Butterfly Construction to extrude an industrial profile with a 9.000t press. The detail of the lead-in plate shows the quality of the machine finishing achievable with a new generation 3D CAM process after the heat treatment.

Moreover, the arrows in figure 5 help to understand how the pressure is broken from the center to the exteriors. The flexion of the mandrel can also be reduced thanks to the arched shape of the two bearing webs in the center that are designed to support the stress and control the flow of aluminium.

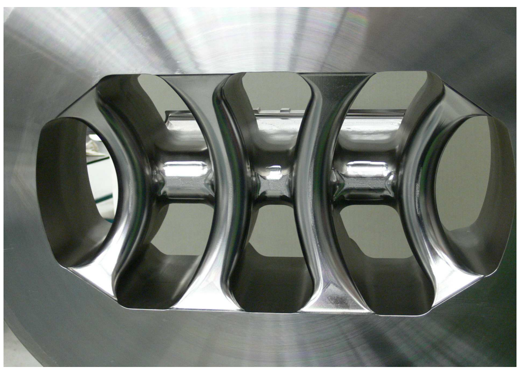

Figure 4: Butterfly Die for a 9.000 MN press; details of mandrel architecture.

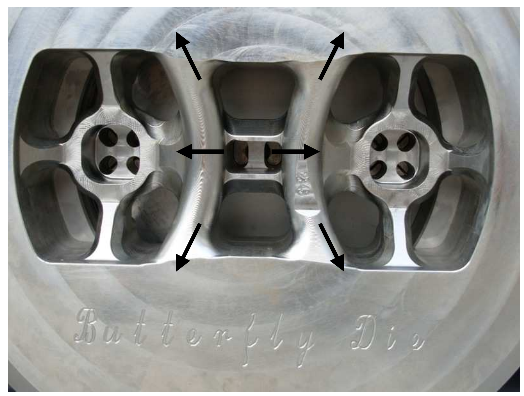

Figure 5: Butterfly Die for a 9.000 MN press; strain distribution on the main bridges.

FURTHER DEVELOPMENTS

The specific needs of our customers pull us towards continuous improvement of our ability to meet their requirements. Today the extruder need to increase the press productivity working in all directions.

In Europe there is more and more the need of a "zero trials" extrusion die already treated (e.g. nitriding, coating) to be ready for production. This means that ports dimension and bearings length must be designed in order to avoid machine and manual intervention during production.

For this reason, we believe that the future of the Butterfly Die™ is related with the engineering of the mandrel section using FEM 3D simulation. The starting point is an Industrial Research Program with European Universities that Almax-Mori will start at the end of the year 2008.

In order to understand the state of the art, we asked one of the most experienced software houses to simulate for us the extrusion of an industrial profile on a 9000t direct extrusion press.

The results obtained can be presented below with the courtesy of Aleris Aluminum Bonn GmbH. Moreover, the software HyperXtrude 8.0 from Altair Engineering has been used for the 3D FEM simulation.

Nowadays the state of the art does not allow to predict the mechanical behaviour of the porthole during extrusion in a reasonable time period. For this reason the structure of the porthole die need to be considered rigid. The main extrusion parameters used to reproduce the real extrusion with HyperXtrude 8.0 are shown in figure 7.

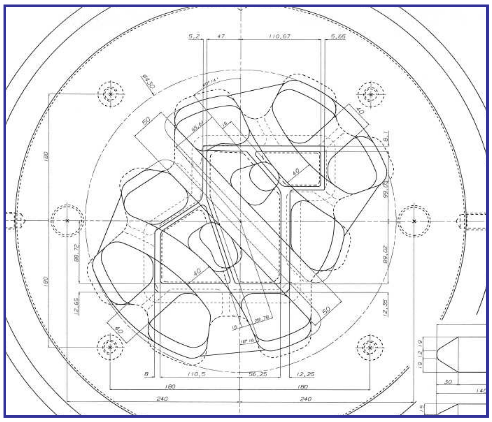

Figure 6: plan of the Butterfly Die™ used for the case study. Property Almax-Mori.

1. Process Parameters
   - Direct Extrusion
   - Container Diameter: 500 mm
   - Aluminum Alloy: 6082
   - Nominal Profile Weight: 21.4 Kg/m
2. Hypothesis
   - Not Flexible Die
3. Boundary Conditions
   - Press Specific Pressure: 46Kg/mm^2
   - Die Preheating Temperature: 470 °C
   - Billet Preheating Temperature: 530 °C
   - Trial RAM Speed: 1 mm/sec

Figure 7: technical parameters used to reproduce the extrusion process. Courtesy of Aleris Aluminum Bonn GmbH.

The software house declared a CPU time of 12 hours, while a time period of at least 48 hours seems necessary to have a results interpretation starting from a complete 3D die design. Considering that the typical lead time for a 750mm diameter porthole die is 4 to 6 weeks, 2-3 days of delay for the 3D simulation seem us acceptable.

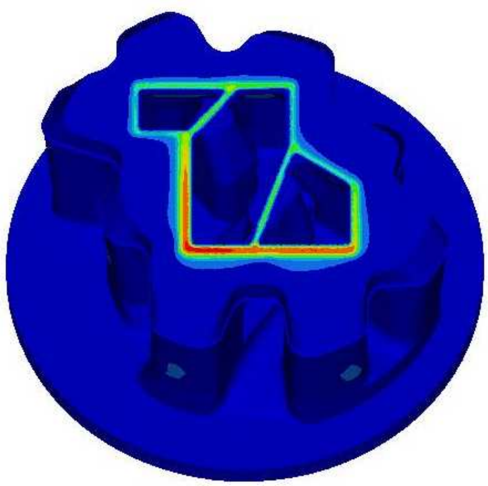

Figure 8: velocity map for the section at the beginning of the bearing length. The sections of the profile in red present an excessive speed.

Figure 9: head of the extruded profile after the first trial at the press.

As shown in figures 8 and 9, the 3D simulation is able to predict the metal flow through the ports giving us a quick response before the beginning of the die manufacturing.

Even with the strong simplifying hypothesis adopted, the FEM simulation can give to the die designer a clear indication over the feeding balance. Costs linked to die trials and corrections can be reduced with a big advantage for the extruder in terms of overall productivity.