State-of-the-Art Die Design for Extrusion of AA6061 Round Pipe

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Editor's Note: "FEA in Extrusion Die Design" is an ongoing series dealing with the opportunities that finite element analysis (FEA) offers to the extrusion industry. Topics will include addressing extrusion defects through die design, the effect of die design on aluminum microstructure, novel approaches to prototyping, and more.

Introduction

Finite element (FE) codes are important tools for process and product optimization for the aluminum extrusion industry. Using numerical simulation, process parameters and die designs can be optimized in order to enhance product properties and to increase productivity at a relatively low cost. When considering the defects typically encountered by extruders, die makers can choose a die concept that helps to minimize those defects as well as further optimizing the design using FEA.

An extrusion engineer should always keep in mind two simple facts regarding recovery and productivity. First, longer extrusions result in a smaller percentage of scrap produced from stop marks and handling equipment (puller, stretcher, etc.) resulting in higher recovery rates. Second, longer extrusions result in less dead cycle time and, therefore, in higher productivity. As a consequence, once an extruder has fixed upon the number of cavities in the die and knows the maximum billet length, they should concentrate on reducing the time required to extrude that length. This can be done by adjusting the alloy, the process, and the die. Dies can significantly influence both ram velocity and front-end scrap thus playing an important role in the metal throughput. This fourth article in the series will focus on how, using advanced state-of-the-art die designs, an extruder can significantly improve the quantity of AA6061 saleable pipe produced per single hour of press operation.

Case Study

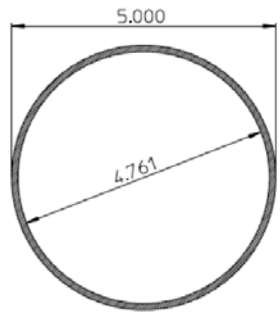

Figure 1. Hollow profile for the AA6061 round pipe under investigation in the case study (dimensions in inches).

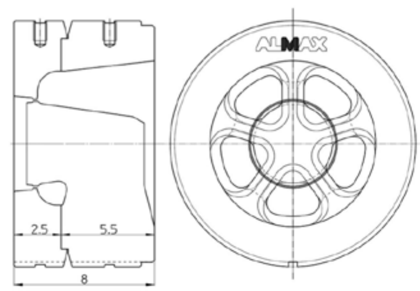

Figure 2. Design A is a traditional die, 14 inches x 8 inches in size.

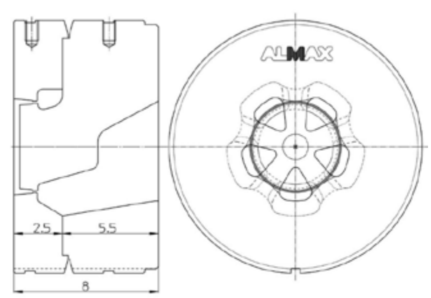

Figure 3: Design B is an inverse pyramid die, 14 inches x 8 inches in size.

Ram Velocity (in/min)	13
Billet Diameter (in)	10
Maximum Billet Length (in)	37
Butt Length (in)	1

Table I. Extrusion parameters used for the case study.

A case study was conducted on a hollow profile (Figure 1) for AA6061 round pipe subject to cold bending operations. Two different tool geometries—Design A (Figure 2) and Design B (Figure 3)—were investigated in order to quantitatively evaluate the effect of different design practices on front-end defect extension. Flow simulations were performed on HyperXtrude software using identical preheating temperatures. The extrusion parameters used for the FEA analysis are listed in Table I.

Design A is a die design solution widely adopted by the industry, with five ports and a recess on the mandrel in order to minimize air entrapment during butt shear operations. Design B is an inverse pyramid die that features five ports like Design A, but has a recess at the mandrel inlet that is pushed to the limit in order to reduce the individual port's volume, introducing a kind of extension of the billet. The aluminum needed to fill Design A is 239 cubic inches and 133 cubic inches in Design B. Moreover, the two porthole die designs have the same thickness for mandrel and cap.

Numerical Results

Design B showed a significant reduction of the front-end defect extension (Table II). This is not a surprise due to the low volume of the ports. With a similar extrudate exit temperature and almost identical break through force, Design B showed a terrific reduction of front-end scrap.

Analytical Results

Based on the numerical results, the author estimated the maximum theoretical recovery and productivity for the two designs investigated using a made-in-house billet length and recovery calculator. Table III notes the assumptions made, based on the industrial extrusion line used to extrude the hollow profile under investigation.

The combination of numerical and analytical results are summarized in Table IV. The inverse pyramid die reduces front-end scrap by 48 inches compared to the traditional die, which has the potential to improve net production by almost 8%.

However, there is a limit to this argument. The author is assuming that 13 inches/min is the maximum achievable ram velocity. If the ram velocity is increased to 15 inches/min, the productivity of the traditional die (Design A) will match the productivity of the inverse pyramid die (Design B) at 13 inch/min. Extruders should focus on reducing the time needed to extrude a required

Design Type	Ports Volume (in^3)	Charge Weld Extension (in)	Break Through Force (MN)	Exit Temperature (°F)
A - Traditional	239	146	26.5	995
B - Inverse Pyramid	133	99	26.5	1005

Table II. Results of the numerical analysis for Design A and B.

Design Type	Cut Length (in)	Dead Cycle (s)	Rear Technical Scrap (in)
A - Traditional	236	15	72
B - Inverse Pyramid	236	15	72

Table III. Assumed maximum theoretical recovery and productivity for Design A and B.

Design Type	Billet Length (in)	Cuts per Billet (units)	Recovery (%)	Productivity (lbs/hour)
A - Traditional	33	5	82	4895
B - Inverse Pyramid	37	6	87	5275

Table IV. Analytical results for Design A and B.

length by working on both scrap reduction and ram velocity.

Conclusion

The case study investigation shows that—contrary to what is commonly thought—big ports do not imply lower cylinder pressures and lower extrudate temperature. Moreover, for relative low production rates like the ones that characterize the extrusion of AA6061 round pipe, a state-of-the-art reduced ports volume die design can significantly reduce front-end defect and, as a consequence, increase the press productivity per hour. Finally, it can be stated that, on the basis of these simple calculations, in order to increase the percentage of saleable material, extruders should focus both on process optimization and die technology. ■

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