CONTROL METHOD OF DEEP DRAWING: KEY VARIABLES INFLUENCING METAL FLOW

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Deep drawing is a sheet metal forming process in which a sheet metal blank is radially drawn into a forming die by the mechanical action of a punch. It is thus a shape transformation process with material retention. Some of the most important aspects of Deep Drawing are as follows:

- Blank Size
- Material Thickness
- Part Shape
- Part Geometry
- Draw Radii
- Draw Ratio
- Lubricants
- Die Surface Finish
- Die Temperature
- Draw Bead Height
- Draw Bead Shape
- N and R Values
- Binder Pressure
- Binder Deflection
- Press Speed

Blank Size, Thickness, Shape, and Part Geometry: Determining the blank size is a very crucial step for a successful draw. The amount of material needed for the final product must be included within the blank. When there are multiple draws for a single product, it can be tricky to determine how much material is needed. Since the draw process causes thinning and thickening of the metals, this is an important first step to a successful draw.

Draw Radii: It is important to note the size, accuracy, and finish of the die entry radius. If the die radius is too small, the material will not easily flow. This results in stretching and fracturing of the drawn product. If the die radius is too large, the material will wrinkle after leaving the pinch point between the draw ring surface and binder. If the wrinkling is extreme, the material flow may be restricted when pulled through the die entry.

Draw Ratio: The draw ratio is one of the most important elements of maintaining successful deep draws. The draw ratio is the relationship between the size of the draw post and size of the blank. During the forming process, the blank is pressed into a circumferential compression which creates a resistance of metal flow. If there is too much resistance, the metal will fracture. If the draw post is not big enough, the metal will stretch, becoming thinner until it cannot be formed. If the draw post is the appropriate distance from the edge of the blank, the metal will be able to flow, while becoming thicker as it enters into the die cavity.

The formula for the draw ratio is: $D/d \leq 2$ for a successful draw.
D = the blank diameter
d = plug (or post) diameter

If this ratio is greater than 2, re-draws (or break downs) are required. In our industry, this is a general rule of thumb. Certain materials may have more accurate, material-specific rule of thumb ratios. For example, Aluminum is 1.8.

Lubricants and Die Surface Finish: Adding lubricants and a polish to the die surface helps with friction and reduces the chance of galling. Galling is when two metallic surfaces slide against each other, creating friction. This can harm the product and the tooling. Applying lubricant to the blank is a very important step in the deep drawing process, to create the highest quality product, while protecting the draw post tooling. Avoiding galling enables the blank to slide easier, allowing for free flowing of the metal.

Die Temperature: The die temperature can cause the lubricant to thicken or thin, depending on how hot the die is. When lubricants heat up, their viscosity drops and they thin out. As they get cold, their viscosity increases. Understanding this relationship is key to creating the best quality drawn part, while maintaining the quality of the die.

It is critical to select the correct lubricant for each deep drawing process. Each lubrication brand, type, and formulation performs differently at different temperatures, depending on their intended use. Certain lubrications need to increase to a certain “working temperature” before they will exhibit any friction-fighting properties at all. In contrast, other lubricants only work in a cold or room-temperature environment. When determining the correct lubrication, the tool temperature, (mid-run and at rest) blank material, and draw severity are all taken into account.

Binder Pressure: At Toledo Metal Spinning, we use pinch and pressure to control the material flow. Binder Pressure is a machine setting that controls the upwards force and/or pressure in the press that will be applied through the draw ring/binder, which sits on top of the cushion pins. The draw ring pressure rises, while the die pressure and slide force is in a downward motion, this is how the blank is “pinched.”

N and R Values: The N value is known as the Work Hardening Exponent, or the Strain Hardening Exponent. This describes steel’s ability to stretch. The larger the material’s N Value is, the more the material is able to elongate without necking, or deforming. The R Value, also known as the Lankford Coefficient or Plastic Strain Ratio, describes the ability of a material to flow or draw. The blank size affects the ability of metal to flow because the press’ speed need to allow for time for the material to flow through. For a more technical explanation, it is a measure of how resistant a metal alloy is to thinning. Mathematically, it is the ratio of the true width strain to the true thickness strain at a specific value of longitudinal strain, up to the point of uniform elongation.

Process Control: The new method tries to improve significantly deep drawing process control considering following requirements: i) selection of the correct process variables in order to monitor real state of the material during the process and command the correction; ii) reduce time consumption for deep drawing process and control system design by reduced order modelling; iii) generation of accurate reference trajectories for the process variables control using FEA and experiments; iv) combine different process control procedures and use those principal capabilities. In this context, the method’s steps are: - first step - we establish the process variables for complex deep-drawing process;

-second step consist in the design of the reduce order model of the deep drawing process; - third step represents the identification of the reference trajectories and control models, using finite element simulation; - the last step in this algorithm (figure 1), consisting in reference trajectories and control models validation it is optional and is applied only for one deep drawn piece belongs to a dimensional group; the decision point selects, function on the answer YES/NO to the question “is it the first piece for the dimensional group?”, if we proceed or no the experimental validation.

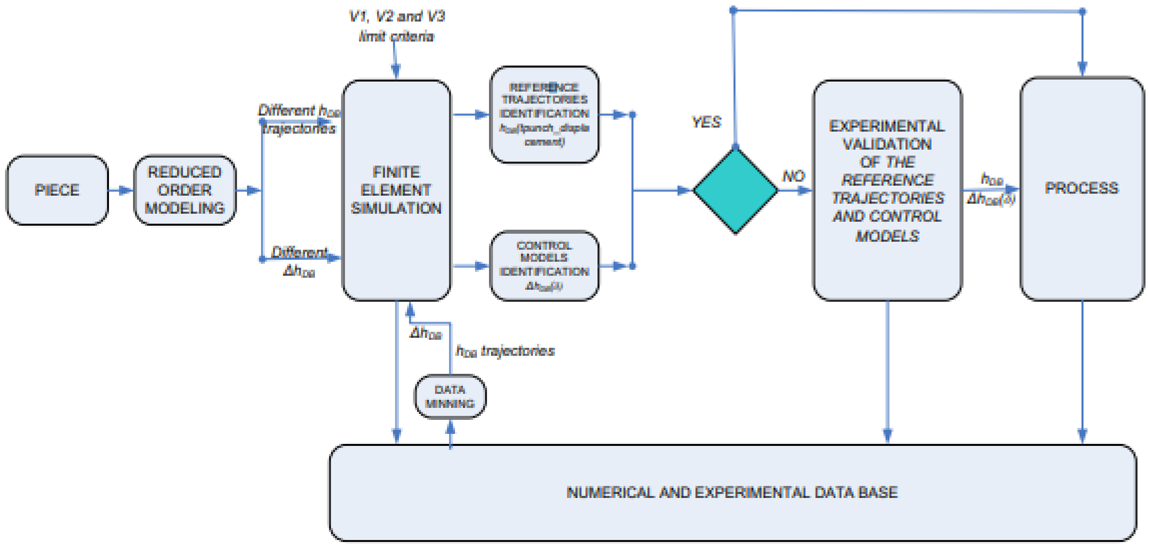

Figure 1: Algorithm of the new control process method

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