

# Multi-step hydroforming process technology of aero-engine guide vane Liner

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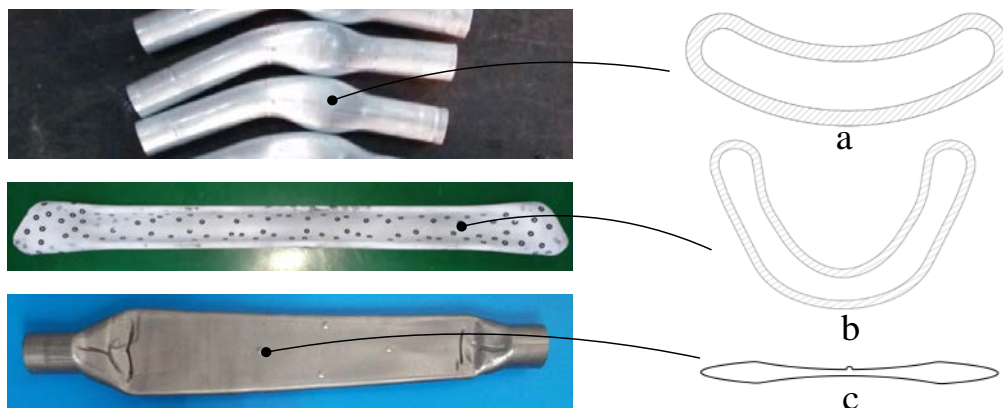
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**Abstract.** In the process of forming large expansion rate parts with complex cross section, the traditional hydroforming process is restricted by the mould surface, and it is difficult for the materials to flow uniformly in the ring, resulting in the failure of forming. Aiming at the above problems, the paper presents a new process of progressive hydroforming process by decomposing the deformation process of the material into two stages of girth increase and shape buckling. The finite element method is used to analyze the distribution of materials in the process of dangerous point forming, so as to establish a progressive forming model and experiment with it. Results show that the multi-step tube hydroforming technology can effectively reduce the thinning of materials at high pressure forming stage, improve the forming precision, reduce equipment load.

## 1. Introduction

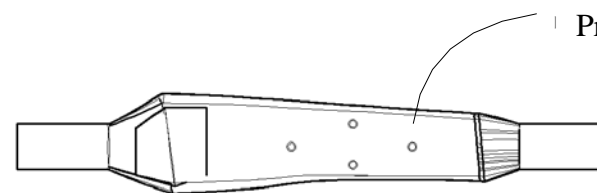
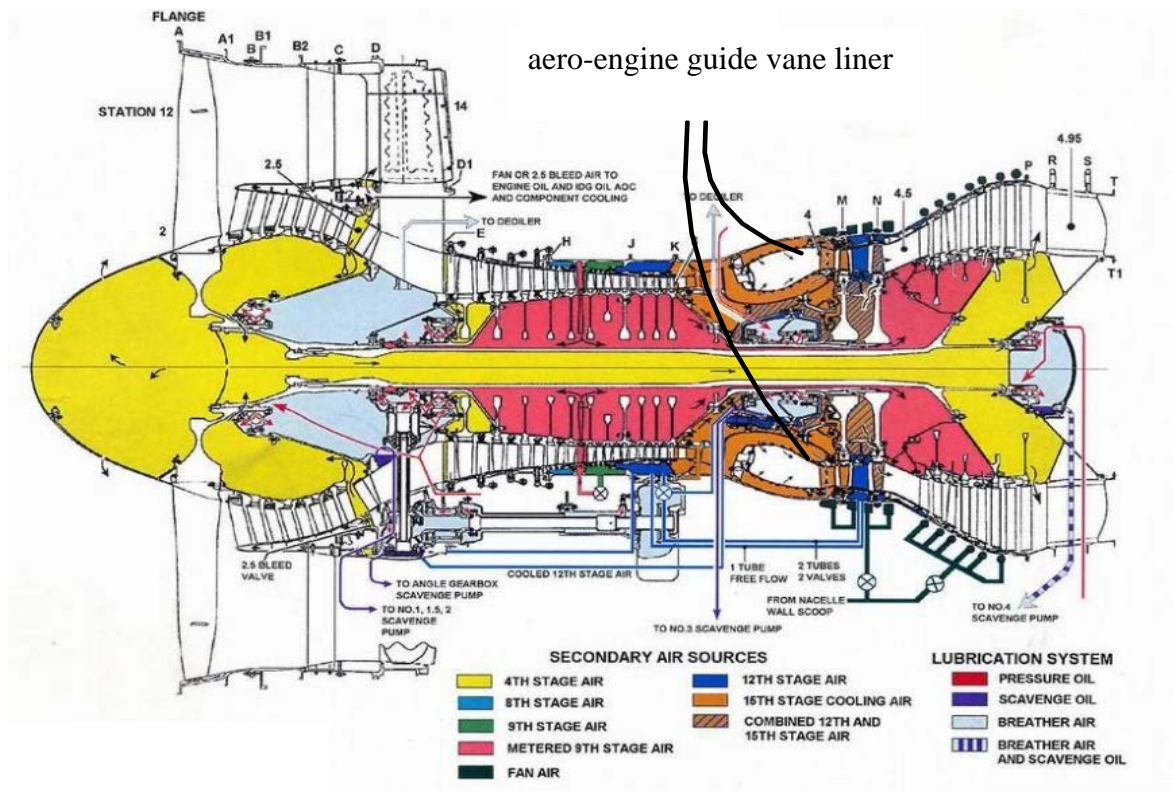
With the increasing demand for lightweight design in the aerospace industries, there are a trends in the design of pipe fittings: parts form more complex, not only increased the amount of expansion, and cross-section complex shape, as shown in Figure 1. For such large expansion rate of complex cross-section components, the traditional pipe filling fluid forming process is difficult to form one by one. In this paper, the section of such a part is summarized as a large aspect ratio rounded surface, the change process of such a surface part in the hydroforming process is studied, the forming difficulties are analyzed, and an improved process is proposed in hydroforming process[1-2].



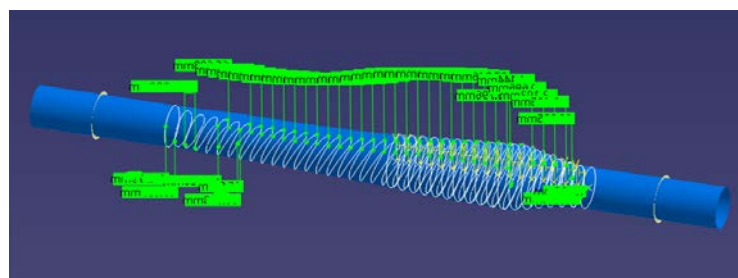
**Figure 1.** Large length width ratio cross section

## 2. Analysis of Forming Process and the Principle of Improvement

Aero-engine Guide Vane Liner is showed in figure 2. The material used for this part is high temperature alloy. The yield strength is 260Mpa, the elongation is 35%, the circumference of the section varies greatly, and the maximum expansion rate reaches 55.7%.

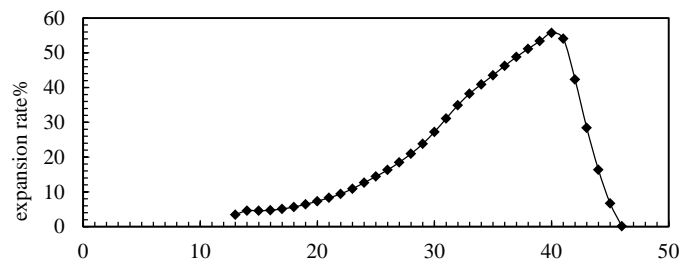


Protruding



(a)

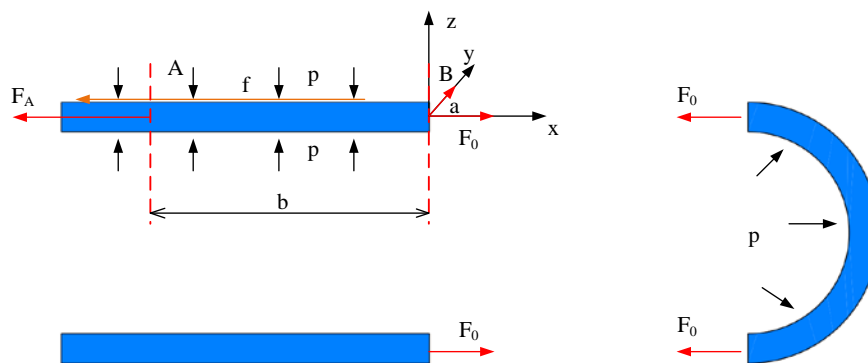
(b)



(c)

**Figure 2.** Aero-engine Guide Vane Liner

According to the force characteristics of the pipe liquid forming, assuming that the pipe is thin-walled tube, ignoring the internal pressure  $P$  in the direction of the thickness of the pipe stress, only to consider the macro role, it can be considered only by axial and circumferential stress pipe stress in the plane stress state. This paper assumes that the billet is infinitely long and in a purely bulge-shaped state without axial feeding, at which time the axial stress can also be neglected. When the long straight edge just completely paste mode, the pressure at this time  $p$ , tube radius of the instantaneous fillet  $r$ , O-O section is the midpoint of the straight edge, A-A section for the straight edge of the region along the  $x$ -axis of any cross-section, B-B cross section is the transition section between the straight edge area and the fillet area. The regional force model as shown below[3-4].

**Figure 3.** Stress state analysis

A-A section of the force balance equation is

$$F_A = F_0 - f \quad (1)$$

$F_A$  A-A section of the internal force along the  $x$ -axis direction (N);

$F_0 = Pra$  B-B section of the extension of the horizontal direction of the internal force (N);

$f = \mu pab$  Friction between the tube and the die shear stress (MPa),  $\mu$  is the friction coefficient;

$a$  The width of the cross-section along the  $y$ -axis extends infinitely close to 0 (mm);

$b$  A-A Section to O-O section horizontal distance (mm);

The stress  $\sigma_x$  along the  $x$ -axis in the A-A section is as follows:

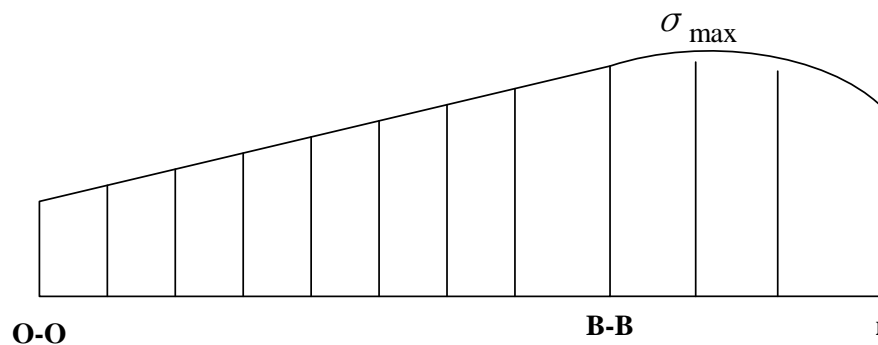
$$\sigma_x = \frac{F_A}{at} = \frac{p(r - \mu b)}{t} \quad (2)$$

The fillet area stress is as follows:

$$\sigma_r = \frac{pr}{t} \quad (3)$$

The  $r_p$  is the instantaneous radius of curvature, and the shape of the corner area is approximate to the ellipse of the long axis extended x direction. The radius of curvature near the corner of the transition zone is larger than the radius of the curvature of the corner vertex. According to the formula (2) and the formula (3), the stress distribution of the circumferential direction of the part can be obtained, as shown in Figure 6. Under the influence of friction, the stress from the symmetrical section of the part right angle O-O to the corner area increases gradually, and the maximum value of  $\sigma_{Max}$  is reached in the overregion. In engineering practice, it is considered that the  $\sigma_{Max}$  is about 1.2 times  $\frac{pr}{t}$ .

When the  $\sigma_{Max}$  is greater than the plastic strength of the material itself, The material began to yield. Therefore, the tube is prone to cracking or necking in the transition region. The ratio of the inner pressure  $P$  to the yield of the part is opposite to the ratio of the diameter to thickness ratio (the ratio of the radius  $r$  to the wall thickness  $t$ ). In engineering applications, because the load of equipment is proportional to the internal pressure, considering the economic benefits, the forming pressure should be controlled below 200MPa and the ratio of diameter to thickness can not be infinitely small.



**Figure 4.** Stress distribution

Through the above analysis, the following conclusions can be drawn

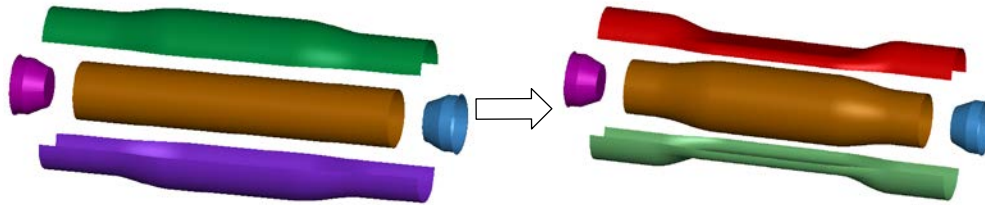
(1) The feature of large aspect ratio fillet enlarges the bulging rate of partial fillet. Excessive local bulging rate can cause excessive tensile rupture in the fillet area even if the ratio of aspect ratio to forming pressure is not considered.

(2) The internal pressure required for forming is affected by the radius-to-diameter ratio, and the fillet formed by increasing the internal pressure is characterized by high cost and low efficiency. In particular, some parts with ultra-high strength even exceed the present forming pressure Equipment capacity, unrealizable in engineering.

### 3. Multi-Step Hydroforming Technology

Any change in the cross-sectional shape of the part during the hydroforming process can be decomposed into the following two modes: an increase of the cross-sectional perimeter and the flow of the material. In conventional hydroforming processes, both kinds of deformation are completed in one process, usually resulting in two variants are not sufficient. Therefore, in view of the above problems, an improved hydroforming process - progressive hydroforming process is proposed. Different

hydroforming processes are designed for different deformation modes to ensure that the two deformations are completed under the most ideal conditions. Make full use of plastic material, thus reducing the difficulty of each deformation.

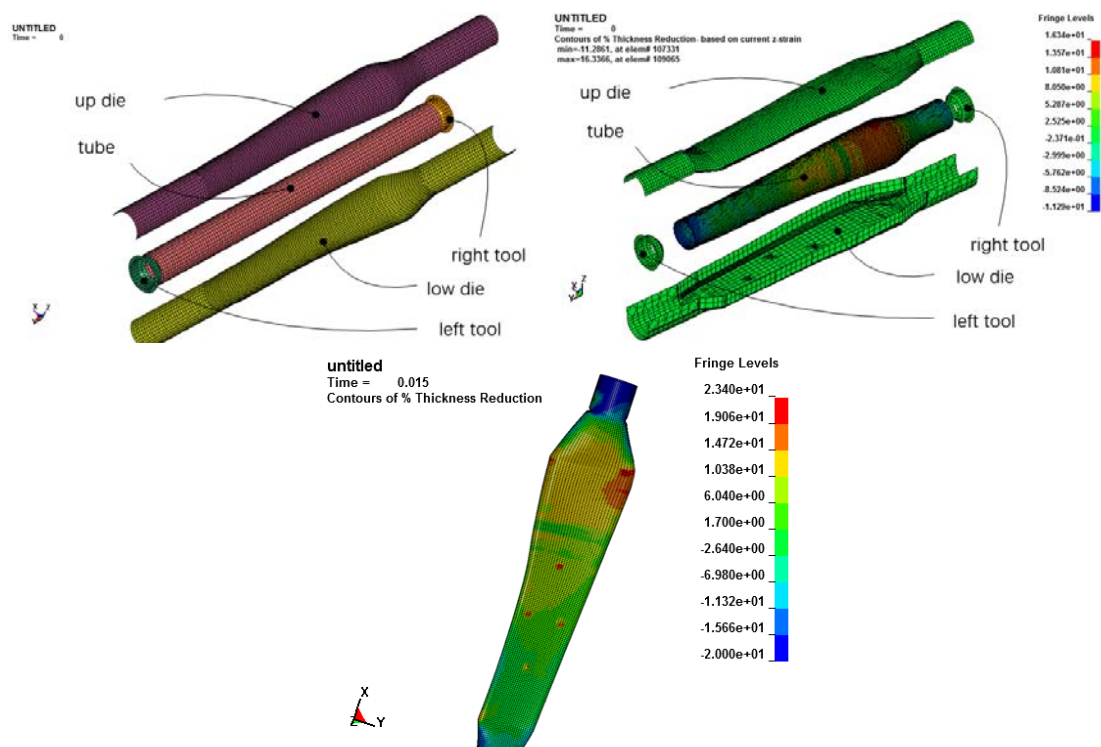


**Figure 5.** Principle of multi-step tube hydro forming

In the case of a circular cross-section bulging, the tube stock is most easily axially fed, and the thinning of the wall thickness is minimized and the amount of bulging is the largest. Therefore, according to progressive filling process to reduce the difficulty of forming each line of thinking, the first part of the hard axis of the region forming a certain interval to do the cross-section, analysis of cross-section relative to the initial bulging amount of the original tube, with the same circumference of the circular cross-section. Instead of complex cross-section in the axis position, the new circular cross-section and the initial tube with smooth surface connected to a new surface, as the first order of bulging surface; the pre-shaped tube into the final mold cavity, this time the length of the part has been bulging in place, just lower the plastic pressure can be shaped in place.

#### 4. Engineering Application

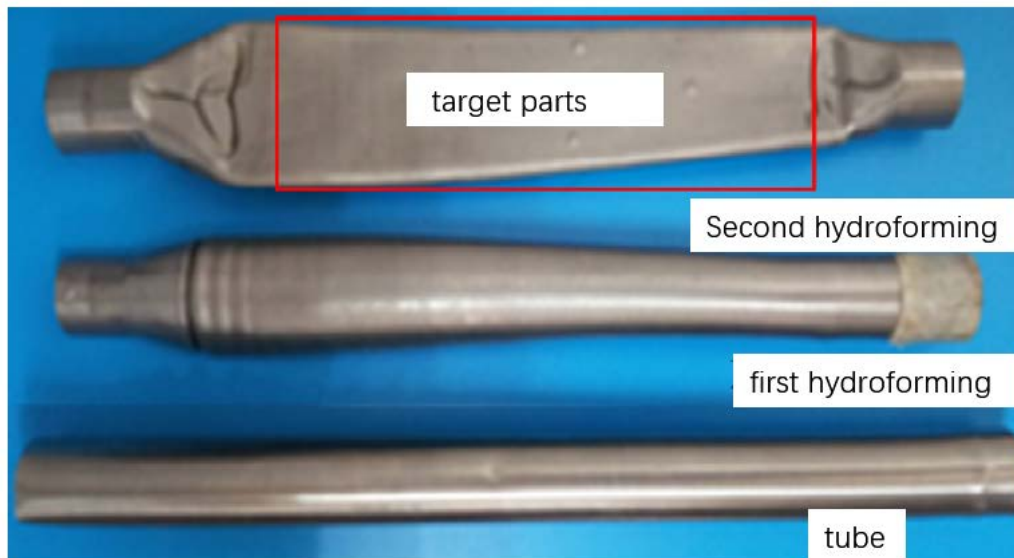
According to the progressive die forming technology, the forming process is decomposed into two steps, and the simulation model is established for each step. After analysis, the final thinning rate of the parts is 26%, without the risk of rupture, and the process is good.



**Figure 6.** Process plan



The experimental results, as shown below, show that the uniformity of the material distribution in the die closing process is improved by adopting the progressive die casting process, and the final forming pressure of the part is 110Mpa, which avoids the rupture. It is proved that the process is suitable for forming superalloy materials.



**Figure 7.** Final plan

## 5. Conclusion

1) In this paper, the forming process of large aspect ratio fillet has been studied, and the influence of aspect ratio, aspect ratio on the formability of the part has been analyzed. The limitation of traditional hydroforming has been pointed out.

2) Based on the theoretical research, an improved progressive filling process is proposed. The hydroforming disassemble the outer circumferential bulging and liquid-filled two-phase, reducing the difficulty of single continuous forming and improve the process reliability.

## References

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