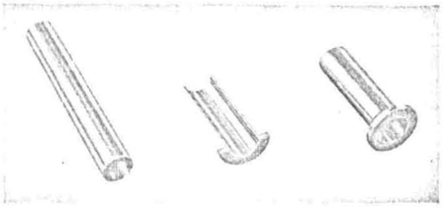

Fig. 14. Tubing flanged under high pressure.

200,000 to 300,000 psi—and the tubing is thus locked by friction to the surface of the mandrel. Now the mandrel can be pushed, or preferably pulled, to cause the tubing to extrude into the flange forming cavity against the back-up die. With this design the extrusion die can be split, because it is easy to seal the high-pressure cavity against extrusion of Teflon plastic.

As illustrated by some of the parts made from it (Figure 14), this version of the flanging process is highly successful. Flanges possessing thicknesses of over eight times the original wall thicknesses have been produced. In this regard one of the interesting features of the process is that, after a certain flange thickness has been reached, little or no additional pressure is required to continue flange growth. Within the flanges themselves the material reaches hardness levels greater than Rockwell B-80 and here again retains toughness. In fact, in the case of 3-inch copper tube the flange material has as high a yield point as the stainless-steel flange previously used.

It might be well at this point to emphasize the fact that the flanging process, although making use of the classic Bridgman pressure-ductility relationship, does not employ fluid. The process thus points the way to a broader, more effective approach to metal-forming problems.

CUTTING OPERATIONS

While hole-punching, blanking, and cutting-off operations are not usually considered metal forming, high-pressure fluids have been used for these purposes. Some of the processes deserve mention.

In the case of flange forming it was found that, if the tube had a smooth inner edge of uniform radius, the preliminary flaring movement was made much easier. Such a curved edge can be obtained quickly and easily by using high-pressure fluid to cut off the tube. By surrounding the tube with a sharp-edged die and then delivering fluid pressure to the inside of the tube opposite the die, it is possible to cut the tube wall neatly in such fashion that the inner edge of the end of the tube is smoothly curved over almost one-half the thickness of the wall.

A similar cutting operation can be used to pierce holes in tubing. In one case, for example, it was desired to pierce a section of waveguide with a number of holes all possessing smoothly curved inner edges. By locating die plates on the outside of the waveguide and subjecting the inside of the waveguide to high-pressure fluid, all the desired holes were punched simultaneously.

CONCLUSION

In summary, the major advantage of high-pressure metal forming lies in the ease with which otherwise separated operations can be combined. Not only can greater deformation be produced in a single operation, but also different areas of a part can be shaped simultaneously by hydrostatic pressure. Thus some very complex shapes can be made at comparatively low cost. And, of course, improved material strength is almost always obtained as a result of the use of high pressure.

Although much progress has been made in the field of high-pressure metal forming, considerable development effort is still required. In particular, research will be of great value in the following areas:

1. Development of long-life seals for very high pressures.
2. Investigation of fluid viscosities and solidification characteristics under pressure.
3. Investigation of the strength and fatigue properties of tool steel under high pressure.
4. Thorough study of the properties of materials after deforming under pressure.
5. Evaluation of the friction properties displayed by material within a high-pressure environment.
6. More extensive and varied tests of ductility under pressure to obtain formability data.

With the proper completion of work in these areas the future of high-pressure forming seems unlimited. Applications for the new processes are numerous, and more are suggested each day.

Aside from the potentially large use of high-pressure forming techniques, the new development presents the materials engineer with a new and very fundamental approach to forming. He is no longer limited by the handbook values of elongation or reduction of area. By the use of suitable pressure he can select the level of ductility he needs for the particular job at hand. Even more important, he now knows the absolute level and directionality of the stress field that must be applied to the workpiece to form a desired part. With this knowledge the materials engineer is armed with a very powerful technique for working out process design details.

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