

HOUSINGS FOR UNDERSEA PHOTONIC SYSTEMS

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1. ABSTRACT

In repeated undersea cables, optical amplifiers and their power sources are housed in hydrostatically sealed containers that must withstand rigorous conditions in service and deployment. In repeated as well as unrepeated cables, cable-to-cable joint boxes must endure similar demands.

As a minimum, these housings are called upon to:

- Remain leak tight for twenty-five years or more.
- Resist corrosive environments and hydrostatic pressure in subsea service.
- Survive mechanical stresses from aggressive handling in deployment.
- Join and seal easily during manufacture and assembly by welding, brazing and soldering.
- Seal completely and reliably in threads and press fit joints.
- Bond well to polymers and elastomers.
- Contain high voltage without danger of arcing.
- Avoid galling or seizing during assembly and cable makeup.
- Maintain precise dimensional stability in manufacture and service.
- Keep components cool by dissipating internally generated heat.

All of this must be achieved at cost that is as low as possible within the constraints of the appropriate specifications, component and assembly drawings, and special instructions.

This paper discusses performance experience, manufacturing technology, quality measures, alternative approaches, and future trends in the production of these component assemblies. The discussion highlights some of the behind-the-scenes contributions that have aided the remarkable advances in the ability of today's photonic systems to keep pace with the worldwide rate of increasing bandwidth demand.

2. INTRODUCTION

The housing that encapsulates and protects undersea optical amplifier systems is an important element in the success of terabit cables. The previous generation housing has demonstrated extremely high reliability in serving the industry throughout its long history. It has done this by complying with rigid specifications on dimensional accuracy, structural integrity, and

mechanical property reliability. The new, higher capacity photonic systems have necessitated the use of housings that are larger in diameter or longer, or both. Tolerances are unchanged, although the components are considerably larger. Strength requirements are undiminished, and in many cases increased because of higher service loads. For these reasons the scale and scope of manufacture have increased significantly. The manufacturing processes involved in this growth are reviewed in this paper.

3. SYSTEMS COMPONENTS

The components that comprise the housing include pressure components and coupling parts. Pressure components include the cylinder and its two end covers which, in the final repeater with inserted photonic and power supply components, are joined by welded or gasketed seals. The housing shields the photonic systems during deployment and service.

A coupling (one at each end of the housing) consists of approximately 12 to 16 different elements that make up a gimbal system that is able to flex and bend in all directions. The coupling protects the fiber during deployment, provides a protective enclosure for the cable-to-repeater fiber splice, and directs the stress arising from cable tension through the high strength housing.

Among the most widely used materials for these components are the high strength copper beryllium alloys. These can be thermally hardened to an ultimate strength of 1000 MPa or greater. This strength level has been routinely achieved in structures for example that are as large as 340 mm outer diameter by 1400 mm long. Branching units requiring the same properties can be as large as 440 mm by 760 mm long. In the hardened condition, the alloys are freely machinable, fusion weld readily, resist galling, have sufficient hardness for handling without special care, and have effective resistance to undersea corrosion.

4. MANUFACTURE

There are two main metalworking processes used to produce repeater and coupling components. These are comprised of several types of extrusion and forging processes. In all methods, the need to develop a high structural quality during the hot working process is of prime importance. Precision nondestructive evaluation techniques such as immersion ultrasonic testing prior to machining and fluorescent penetrant examination after

machining are widely required on the most design critical components.

Alternative manufacturing methods such as powder metal processing, or metal-matrix or polymer-matrix composites and the like are sometimes proposed but cost considerations as determined by the size and complexity have made these uneconomical.

Structural quality in a cast and hot worked product depends on the cast billet fineness and integrity as well as the degree and uniformity of hot working.

For the pressure housings, cast starting billets must be as large as possible, consistent with the diameter of the finished cylinder unit. The direct chill casting process is amenable for production of large sections with uniform structural fineness. A relatively high percentage of hot working of the cast structure is mandatory in order to achieve the required strength and structure for service durability.

The cast structure contains the memory of solidification, specifically a dendritic microstructure and traces of unavoidable microporosity. Hot working acts to break-up the dendritic structure and seals interdendritic microvoids through deformation and recrystallization. Achievement of a sound structure requires that sufficient strain is present to cause structure refinement through dynamic recrystallization, and specifically that a critical level of strain be achieved throughout the workpiece. Strain is not necessarily accumulative in hot working processes, and, in fact, low levels of strain and non-symmetric strain can be detrimental in the production of structural nonuniformity. As housing structures become larger, the need to avoid asymmetric or insufficient levels of strain increases.

In working the cast billet into the repeater housing shape a common, but costly practice is to employ two hot working deformation steps. The purpose of the first step is to condition the casting for final hot working; that of the second is to form the near net housing shape.

The indirect or reverse extrusion process offers the opportunity to economically combine the two operations into one for a modern repeater system. In this method, a structure tailored for this application is formed through a single working step. The process has a long history of successful performance in the undersea environment and the product has performed with nearly perfect reliability. In recent months it has been successfully scaled up to house the new 8 amp pair photonic systems. After hot working, thermal treatment, roughing, and finish machining are required to finish the cylinder.

The structure conditioning process is a high temperature deformation that substantially reduces the

diameter of the large cast billet. This can be radial forging or cogging. If the cast billet is less than about 450 mm in diameter, it is best if the billet is upset forged to increase the diameter, then open die forged to draw it out to length. The deformation imposed in this step must be sufficient to dynamically recrystallize throughout the workpiece so that the cast condition is replaced by a hot worked structure.

The applicable shaping steps are described briefly in the following sections.

4.1 Extrusion

Extrusion is commonly used to convert a billet into lengths of product that have a uniform cross section. In forward (direct) extrusion, the press ram pushes the billet through a die to produce the product. The flow of metal is therefore in the same direction as the ram motion. In backward or indirect extrusion, the ram moves into the billet, causing it to flow around the ram in a direction opposite to the ram motion. While both forward and backward extrusion can produce tubular shapes, there are large differences in starting stock, tooling, and process economics between the processes.

4.1.1 Forward Extrusion

In the forward extrusion process a billet is extruded through a die that has a mandrel located in the die throat so that a hollow shape is formed. This process is illustrated in Figure 1. The mandrel pierces the workpiece to start the extrusion and then acts as an inner die as the tube is formed. The outer diameter is substantially reduced and a heavily worked tube wall (usually greater than 10 to 1 area ratio) is formed.

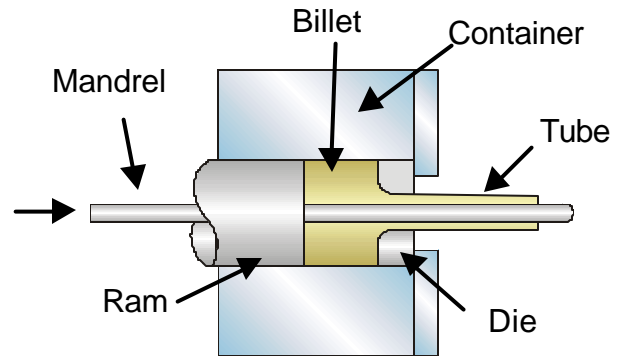


Figure 1. Forward Extrusion of Tubular Product

The preshaped billet can be as cast or for special requirements, open die forged. In either case it is machined or pierced to produce a cylindrical billet with a cavity that accepts the fixed mandrel of the extrusion ram. As the nose of the billet is pushed through the die, the mandrel advances and passes through the outer die so that it in turn acts as an inner die. The net effect is that the outer diameter is reduced, the tube wall is

deformed heavily, and the inner diameter is sized by the mandrel.

The process incorporates the basic advantages of extrusion deformation in producing a structurally sound product. Care must be taken to insure wall thickness uniformity, often by providing sufficient metal on the outer and inner tube walls for ease in finish machining.

Many of the coupling components, such as the sleeve that houses the fiber splice in cable to repeater and cable to cable splices are made by this process, as are the various ring members of the gimbal assembly. As a thoroughly hot worked product, the response to thermal hardening is effective in achieving targeted strength and hardness.

4.1.2 Indirect Extrusion

In this process, a solid billet is placed in a blind die cavity and a ram forces a punch into the workpiece, as shown in Figure 2. The punch constitutes the die, and metal flows back along the stem to form the hollow shape. At the end of the stroke a canister shape has been formed, with the closed end requiring removal by machining or trimming.

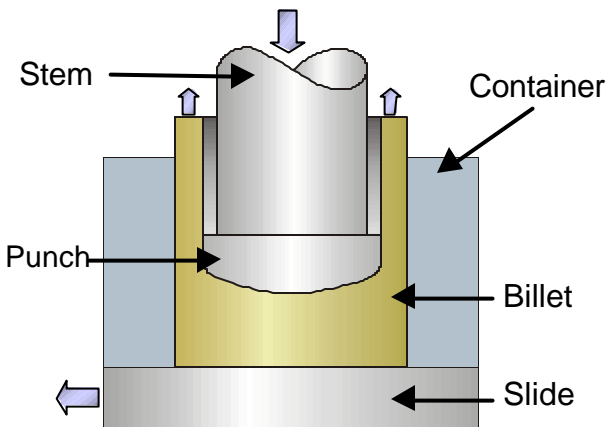


Figure 2. Indirect Extrusion of an Undersea Repeater Housing Cylinder.

Indirect extrusion has the advantage that the outer diameter does not change from the billet to the product. Except at the very leading end of the canister, a large reduction is taken for effective conditioning. The leading end is trimmed as well. The process requires lower extrusion loads than the equivalent forward extrusion because the friction force between the extrusion container and the billet is eliminated. This process is economical by virtue of simplified tooling, the uncomplicated workpiece shape, and process reproducibility.

4.2 Radial Forging

Radial forging is used to reduce the diameter of long billets. It is an incremental process in that a sequence of deformation steps is required to achieve the reduction along the entire billet length. The level of deformation therefore varies within a range of local strains throughout the volume of the billet. Hollow billets may be radially forged over a mandrel with processes such as saddle forging or swaging, but the length achievable and the use of specialized equipment limit the process.

Multiple hammer radial forging reduces the outer diameter and increases the billet length. This process provides somewhat less uniform deformation than extrusion, and uses specialized process equipment. The small hammer footprint and the limited stroke limit uniformity. In combination, these features create a surface to interior strain differential, and consequently, a structural differential from the outer to inner walls.

Radial forging of a solid billet followed by trepanning may also be used. In this process, a cast billet is radially forged in multiple passes, commonly from a large diameter to a smaller diameter, see Figure 3.

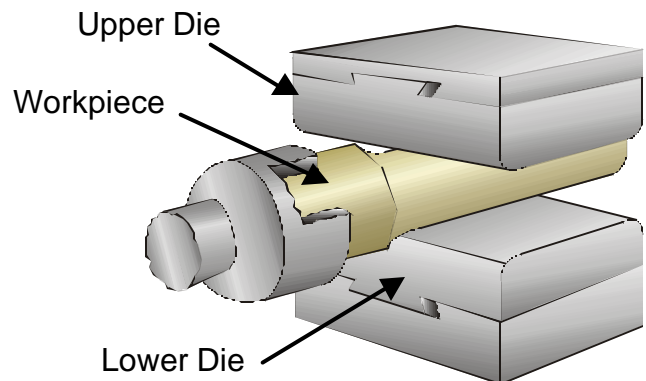


Figure 3. Open Die Forging of Coupling Parts or Repeater Cylinder.

Considerations of this process include the loss of material from the center of the forging, as well as the intermittent nature of deformation.

In the draw forging, or cogging, process, a common method for breaking up the cast structure of an ingot, a press with opposing rams is used to reduce the billet diameter. The finished cogged billet must be trepanned to produce a hollow cylinder. The size of the die footprint is large compared to that of multiple hammer radial forging, as is the length of the deformation stroke. Therefore, the resultant volume of metal that is strained per machine blow is larger. Surface-to-center strain is more uniform than in multiple hammer forging, but the shape is not as smooth. The finished diameter is often left larger, or the part is made octagonal to ease machining.

4.3 Other Processes

The closed die forging process is used to provide economy in forming a near net shape for complex shapes such as end covers. The process requires a shaped die to be produced that takes on the shape of the outer and inner contours of the part. In this process the metal structure is designed to generally follow the machining contour, thus providing added stability.

Precision sand castings are extremely valuable in producing complex shaped components that do not need to withstand the full pressure of the undersea environment. With these alloys, the strength achieved by a cast, solution treated, and age hardened process is sufficient for use in cones and coupling guides among other parts.

Small diameter rod such as is needed for pins and fasteners, is cold drawn for precision and added strength. Retaining rings and straps are produced from flat products such as strip that is cold rolled and age hardened prior to slitting and stamping.

5. SUMMARY

High quality repeater housing components and coupling assemblies are produced by a variety of conventional hot working techniques.

For the repeater cylinder, each technique acts to hot work a carefully prepared cast billet into a cylindrical form by methods that combine development of a suitable structure with achievement of a near net shape. Of the available methods the combination of process capability and process efficiency favors indirect extrusion of the cylindrical shape. Indirect extrusion uses a simply shaped workpiece, the tooling is not complicated, and the process is robust. Since the deformation is uniform, the billet is subject to more uniform stress relief during heat treatment. Distortion on machining and welding is minimized. The structure produced by the hot extrusion operation is sound and the performance of the housing meets or exceeds all requirements.

Coupling components and joint box components are forward extruded when tubular shapes are required. Open die forging is generally used when massive components are machined from solid rod or similar shapes

6. HEALTH AND SAFETY

Handling copper beryllium alloys in solid form poses no special health risk. Like many industrial materials, beryllium-containing materials may pose a health risk if recommended safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious

lung disorder in susceptible individuals. The Occupational Safety and Health Administration (OSHA) has set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Material Safety Data Sheet (MSDS) before working with this material. For additional information on safe handling practices or technical data on copper beryllium, contact Brush Wellman Inc.

7. ACKNOWLEDGEMENTS

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