PRODUCTION LIFE OF TUBE SWIMMERS

Two humped mandrels, called swimmers, are used in the special tube drawing process of Bundy Tubing Company to size internal diameters of tubes formed from double-wrapped steel strip. The aim of this study was to determine key factors to promote increased life of swimmers which currently fail mostly by metal pick-up. There was insufficient data to build mathematical models for swimmer failure; it is recommended that systematic data collection take place using statistical quality control principles.

1. Introduction

Bundy Tubing Company (Australia) produces small bore steel tubing, ranging from a bore size of 3.33 mm to 11.28mm and wall thickness typically 0.71mm. The manufacturing process begins by passing thin, copper-plated steel strip through a series of rollers until it forms a double wrap tube shape as shown in Figure 1(a).

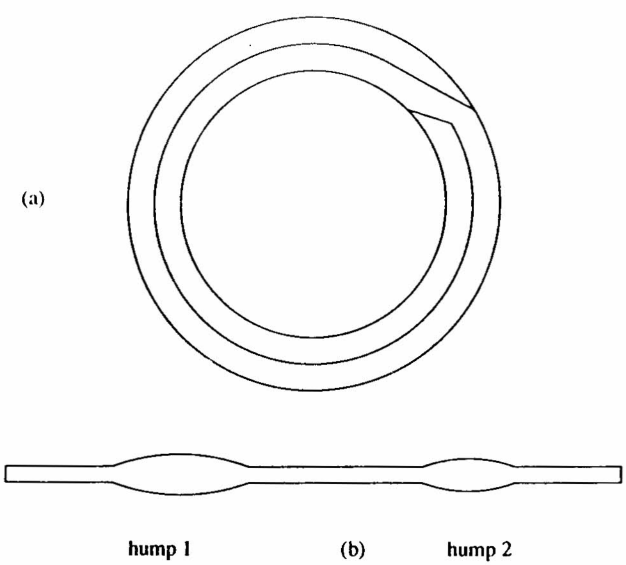

Figure 1: (a) A double wrapped tube. (b) A swimmer. (Different scales.)

Long sections of this tube, approximately 30 metres in length, are then passed through a furnace kept at 1100°C, some 20°C above the melting point of copper. Fusion of copper and cooling produces tube with solid walls.

The internal diameter of the tube is determined at the final stage of rolling by using a lubricated, chrome-plated, hardened steel plug called a swimmer hump. It is located inside the tube at a fixed position between a pair of finishing rollers. The squeezing of double wrapped tube between rollers and swimmer hump causes plastic thinning of the walls and an elongation typically 10%. Current swimmer mandrel design consists of a chrome-plated rod and two humps (see Figure 1(b)), one of which is designed for thinning and the other, located under the second last pair of rollers, is for guiding. The swimmer is used until failure and then replaced. In at least 90% of cases failure is by "pick-up" of excess copper from the strip onto the thinning swimmer hump.

Although the cost of a swimmer is not high (about $10), many thousand are used per year. It is desirable to reduce costs by optimising the operational life of swimmers (order 1 hour) both in their design and use as part of the complete tube making process.

2. Discussion

Bundy tube making uses a metal drawing process which apparently has not been treated in the open literature, although it has similarities to plug drawing through fixed dies (Rowe, 1977). Advancement of understanding in traditional problems in tribology have come as a combination of experiment and mathematical modelling (Bowden & Tabor, 1950, 1964; Cameron, 1966). Here we were faced with insufficient experimental data to determine the causes of failure which led to the final pick-up of copper. Without such data, only qualitative suggestions can be made to establish the current state of operations and trends for improvement — merely focussing on one aspect, such as optimising swimmer hump profiles to minimise redundant plastic work, could be unimportant.

Considerable effort was spent during the Study Group looking at possible mechanisms of failure, the mode of lubrication – whether boundary or thin film or some combination of the two – and design possibilities for improved swimmer cooling. From these discussions, the necessity of systematically collecting data became clear, both to establish optimum operational conditions for minimum cost and to guide any future modelling based on a sound knowledge of failure mechanism. The recommendations of what needs to be done for these two aspects are set out below.

(a) Optimum swimmer design

It is first necessary to establish the metallurgical mode of failure which leads to pick-up in the current process and whether the location of pick-up is initiated from a random point on the swimmer surface or at a preferred point. Such preferred points are likely to be where the wrapping of tube begins at the inner bevelled edge, and the opposing positions where pressure from the finishing rolls is greatest or least. Possible modes of failure are structural changes to the swimmer substrate brought on by sustained elevated temperatures, which could weaken the support or bonding of the chromium layer, and general surface wear with debris collection. Large random variations in strip thickness could also be a significant cause.

If the failure mechanism could be established, then a mathematical model could be constructed to address aspects such as the relative importance of temperature distributions, applied loads, rolling speeds and lubrication conditions.

Items to be examined are:

Swimmers: Manufacturing quality control; alternative coatings to chromium; shape optimisation to reduce redundant work; relative hump sizes for sharing of plastic work and altering lubrication; possible surface lubrication grooves; and rotation if preferred failure point occurs.

Strip: Thickness variation control; quality of edge bevelling for compact wrapping (and bevel adjustment in rollers); and surface cleanliness.

Finishing Rolls: Cross sectional shape to improve pressure distribution around tube thence swimmer — this may include interlocking of roll pairs to inhibit roll side movement; and optimum speed determination.

Lubrication: If possible, improve lubricant; and establish plastohydrodynamic lubrication (Naurhia, 1987).

(b) Optimum swimmer changes in production

With any swimmer and rolling conditions, it is conceivable that it is more profitable to discard swimmers *before* their mean life expectancy thereby optimising the overall production costs. The optimum would involve swimmer cost, labour costs for changing to new strip reels (normally of order 1 km in length, and a mean between 3 and 16 reels used) and tube wastage caused by uncertainty in establishing pick-up failure. To establish this procedure, swimmer life distributions need to be established accounting for swimmer sizes and quality and strip quality.

3. Conclusions

Considerations of possible mechanisms for swimmer failure, mode of lubrication and heat transfer led to the conclusion that detailed modelling was inappropriate without further data.

For an improvement in the operational life of swimmers it is important to gather data systematically as advocated in current Quality Control procedures (Kjar & Hobbs, 1991). Statistics on swimmer lifetime variability need to be established to determine the factors of importance and their sensitivity to incremental changes. From these statistics, optimum operational costs for usage of swimmers can be established.

It is also very desirable for potential major improvements to find the current metallurgical failure mechanism, from which can be gauged the value of changes to swimmer material, shape and production quality control, lubrication, cooling, finishing roll design and speed, and tube strip bevelling, thickness variation and cleanliness.

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