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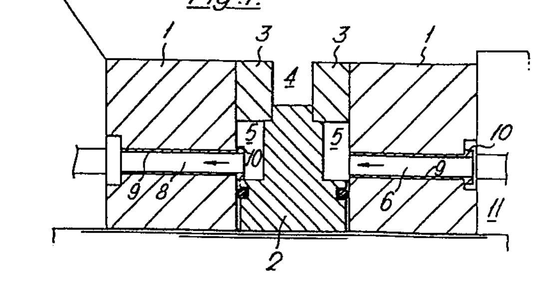
(54) **Extrusion machinery.**

(57) In Conform machinery for continuous friction actuated extrusion the wheel is made up of at least three parts, namely two cheeks with a hub between them. Annular coolant passages extend between these members and are fed by ducts (6, 8) which extend at least through the cheek members. These ducts, and any extending through the hub are lined with thermally-insulating material (10) such as PTFE. This greatly reduces thermal stresses around the coolant ducts, which can be a cause of premature and catastrophic failure of the wheel.

Fig. 1.



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EXTRUSION MACHINERY

This invention relates to machinery for continuous friction-effected extrusion, primarily but not exclusively of metal. More particularly it relates to machinery of the kind in which a passageway is formed between an arcuate first member and a second member in the form of a wheel having a circumferential groove formed in its peripheral surface into which groove the first member projects, the wheel being rotatable to urge material in the passageway towards one end (the exit end) thereof, an abutment member extending across the passageway at the exit end thereof and at least one die orifice through the abutment member or through an adjacent part of the arcuate first member.

The abutment member may be large enough to block the end of the passageway completely (as described in the specification of UK Patent 1370894) but especially when the material to be extruded is a relatively hard metal, such as copper, we prefer that the abutment member is of substantially smaller cross-section than the passageway and leaves a substantial gap between the abutment member and the groove surface and that the material being extruded is allowed to adhere to the groove surface, whereby a substantial proportion of the metal (as distinct from the inevitable leakage of flash through a working clearance) extends through the clearance and remains as a lining in the groove to re-enter the passageway while the remainder of the metal extrudes through the die orifice(s), as described in our UK Patent No. 2069389B.

Such machinery is commonly known as "Conform" machinery, and will be referred to as such hereinafter.

The wheel of Conform machinery is subject to very high, and cyclic, stresses and is liable to premature failure though fatigue cracking, which adversely affects the operation of the machinery through high down-time and considerable replacement cost.

The fatigue cracking problem has led to the adoption, in place of a monolithic wheel construction, of a wheel comprising two cheek members and a central hub which forms the base of the passageway. Hitherto the cheek members have usually formed the sidewalls of the passageway, but it has been suggested the sidewalls of the wheel groove should be formed by separate rings; we have experimented with such arrangements and found it desirable to provide slip surfaces between the cheek members and the rings which are generally parallel to the sidewalls and spaced from them a distance not less than half nor more than twice the width of the wheel groove, subject to a minimum distance of 3 mm.

These two forms of wheel (for brevity hereinafter called "three-part" and "five-part" wheels respectively, though either may and will usually have further, auxiliary, parts) are customarily cooled by water or other fluid coolant flowing in annular passageways between the parts, and it is a practical necessity for coolant to be fed to and received from the annular passageways by ducts extending through the cheek members; usually there are ducts through the hub as well, the most usual arrangement being for the flow to be inwards through each of four equally spaced entry ducts in one cheek member, around one eighth of the wheel circumference, through a transfer duct extending through the hub, back around the circumference (subject to the effect of mixing with flow from the next entry duct) and out through an exit duct through the other cheek member axially aligned with the respective entry duct.

Inevitably the walls of these coolant ducts are at considerably lower temperatures than the remainder of the respective wheel member in which the ducts are formed, so producing stress concentrations around the ducts that frequently lead to cracking and catastrophic failure of the wheel.

The present invention substantially reduces this effect and so enhances average wheel life.

In accordance with the invention the coolant ducts through the cheek members at least (and preferably through the hub also when applicable) are lined with thermally insulating material so that cooling is concentrated at the surfaces of the annular passageways between the parts.

Any adequately heat- and fluid-resistant thermally insulating material can be used, but we prefer a heat-resistant plastics material such as PTFE (polytetrafluoroethylene). Either a coating or a pre-formed close-fitting sleeve can be used; a thickness of around 0.05 mm gives an appreciable benefit but a thickness of

1-1.5 mm is recommended. When a pre-formed sleeve is used it is preferably flanged at the upstream end to secure it against movement in the direction of coolant flow.

To avoid another source of weakness, preferably no keyways are used to transmit drive between parts of the wheel.

The invention will be further described, by way of example, with reference to the accompanying drawings in which: Figures 1 and 2 are cross-sections through the significant components of the wheel of a Conform machine in accordance with the invention at two places spaced round the circumference of the wheel by 45°; and Figure 3 is a diagram illustrating the distribution of coolant flow through the wheel.

The wheel comprises two cheek members 1, a hub 2 and a pair of rings 3. The rings 3 and the hub 2 bound the working groove 4 and all these members are exposed to a pair of annular coolant passages 5. Entry and exit ducts 6, 8 through the cheek members and transfer ducts 7 through the hub provide for through flow of fluid and, in accordance with the invention, these ducts 6, 7, 8 are lined with PTFE tubes 9 which have flanges 10 at the end at which coolant is to enter them.

As best understood from Figure 3, the coolant enters from the wheel member 11 in a conventional manner and passes through any one of the inlet ducts 6 in the right hand cheek member 6 which conveys it to the first (right hand) annular passage 5. Here the flow divides to pass in both directions around the annular passageway 5. After flowing round about 45° (relative to the axis of the wheel) the flow encounters oppositely-flowing coolant which entered at the next of the inlet ducts 6, mixes with it, and flows through the duct 7 to the second (left hand) annular passageway. Here the mixed flow divides again, flowing in both directions around the passageway to leave by the exit ducts 8 which are aligned with the entry ducts 6 through which it first came. (In Figure 3, I-I and II-II each indicate one of the four equivalent positions corresponding to Figures 1 and 2 respectively).

In a practical example, a Conform machine had a wheel of the design shown in Figures 1 and 2 with a circumference of one metre and a groove substantially nine millimetres square. The coolant ducts (6, 7, 8) were 8 mm in diameter, and the PTFE sleeves 10 had an internal diameter of 6 mm and a wall thickness of 1 mm, so as to fit the ducts without nominal clearance. The flanges 10 were 2 mm thick and had an outside diameter of 10 mm.

The quantitative effect of these thermally-insulating tubes may be estimated as follows:-

For an infinite hollow circular cylinder with internal and external radii of a and b respectively that has a temperature T_a at radius r = a and T_b at r = b, the temperature distributions T(r) is given by Conduction of Heat in Solids, H. S. Carslow & J. C. Jaeger, Oxford University Press 1959

$$T(r) = \frac{T_a \ln\left(\frac{b}{r}\right) + T_b \ln\left(\frac{r}{a}\right)}{\ln\left(\frac{b}{a}\right)} \qquad (1)$$

The circumferential component if stress σ_Θ due to a temperature distribution T(r) is given by Theory of Elasticity, S. Timoshenko & J. N. Goodier, McGraw Hill 1951

$$\sigma_\Theta = \frac{\alpha E}{1 - \nu} \frac{1}{r^2} \left\{ \left(\frac{r^2 + a^2}{b^2 - a^2} \right) \int_a^b rT(r) \; dr + \int_a^r rT(r) \; dr - r^2 T(r)^2 \right\}$$

Where α is the thermal expansion coefficient, E the Youngs Modulus and ν is a constant.

Then, since

$$\int r\,T(r) \; dr = \frac{r^2}{2\ln\,(\frac{b}{a})} \left\{ Ta \ln\,(\frac{b}{r}) + Tb \ln\,(\frac{r}{a}) - \frac{Tb - Ta}{2} \right\}$$

substituting in (2) and evaluating at r = a, gives (3)

$$\sigma_\Theta = \frac{\alpha E (Tb - Ta)}{1 - \nu} \left\{ \frac{1}{1 - (\frac{a}{b})^2} - \frac{1}{2\ln\,(\frac{b}{a})} \right\} \text{ at } r = a$$

For very large $\frac{b}{a}$ (such that $\frac{1}{2\ln\,\frac{b}{a}}$ may be neglected)

we have $\sigma_\Theta = \dfrac{\alpha E (T_b - T_a),}{1 - \nu}$ (4)

but even with $\frac{b}{a}$ as small as 5,

(3) gives $\sigma_\Theta = 0.73 \dfrac{\alpha E (T_b - T^a),}{1 - \nu}$

Thus for large $(\frac{b}{a})$ the stress given by (3) is not critically dependent on $(\frac{b}{a})$ and (4) can be used as a fair approximation to the hoop stress around the small hole in an irregularly shaped solid.

Taking values for BH13 steel

$E = 2.16 \times 10^{11} N/m^2$

$\alpha = 1.25 \times 10^{-5} {}^\circ C^{-1}$

$\nu = 0.3$, and assuming $T_b - T_a = 50^\circ C$

gives, using (4), $\sigma_\Theta = 190\ MN/m^2$

The effect of introducing a sleeve of thermal conductivity K, and internal radius c into the hole in Figure 1 and then taking the internal radius to be at temperature T_a, is to modify the temperature at r = a to be

$$Ta^1 = \frac{K_1\ Ta\ \ln(\frac{b}{a}) + K_2\ Tb\ \ln(\frac{a}{c})}{K_1\ \ln(\frac{b}{a}) + K_2\ \ln(\frac{a}{c})} \qquad (5)$$

Taking K_2 = thermal conductivity of H13 = 25 $Wm^{-1} {}^\circ C^{-1}$

K_1 = thermal conductivity of PTFE = 0.015 $Wm^{-1} {}^\circ C^{-1}$

and if $\frac{a}{c}$ is of the order of 1.5 then unless $\frac{b}{c}$ were to exceed say 10^{30},

then $T_a^1 \simeq T_b$ and the thermal stress is almost entirely removed.

Because our researches revealed a number of sources of weakness which were dealt with together, a strict experimental comparison is not available. However, when a wheel of the same major dimensions but with the groove formed directly by the cheek members and a flat hub was used to extrude particulate copper, seven failures of the cheek members occurred by the time 170 tonnes of copper had been extruded (mean 24 tonnes per failure). Examination showed that two of these failures had been initiated at coolant bores (once such failure per 112 tonnes). The others were initiated at keyways (3), at a sharply machined internal corner (1) and at a groove corner (1) and are not relevant to the present invention.

The elimination of keyways and use of separate rings 3 is considered unlikely to have had any significant effect on the rate of failure at coolant ducts; the machine described herein by way of example has so far extruded 260 tonnes of copper under the same conditions without any failures of the cheek members whatsoever.

CLAIMS

1. Conform machinery in which the wheel comprises two cheek members and a central hub with provision for coolant flow in annular passageways between the cheek members and the hub including ducts extending through the cheek members distinguished by the fact that the ducts through the cheek members are lined with thermally-insulating material so that cooling is concentrated at the surfaces of the annular passageways between the parts.

2. Conform machinery in accordance with Claim 1 in which ducts through the hub are also lined with thermally-insulating material.

3. Conform machinery as claimed in Claim 1 or Claim 2 in which the wheel groove is formed by the central hub and two rings separate from the cheek members.

4. Conform machinery as claimed in Claim 3 in which slip surfaces between the cheek members and the rings are generally parallel to the sidewalls of the groove and spaced from them a distance not less than half nor more than twice the width of the wheel groove, subject to a minimum distance of 3 mm.

5. Conform machinery as claimed in any one of the preceding claims in which no keyways are used between parts of the wheel.

Fig.1.

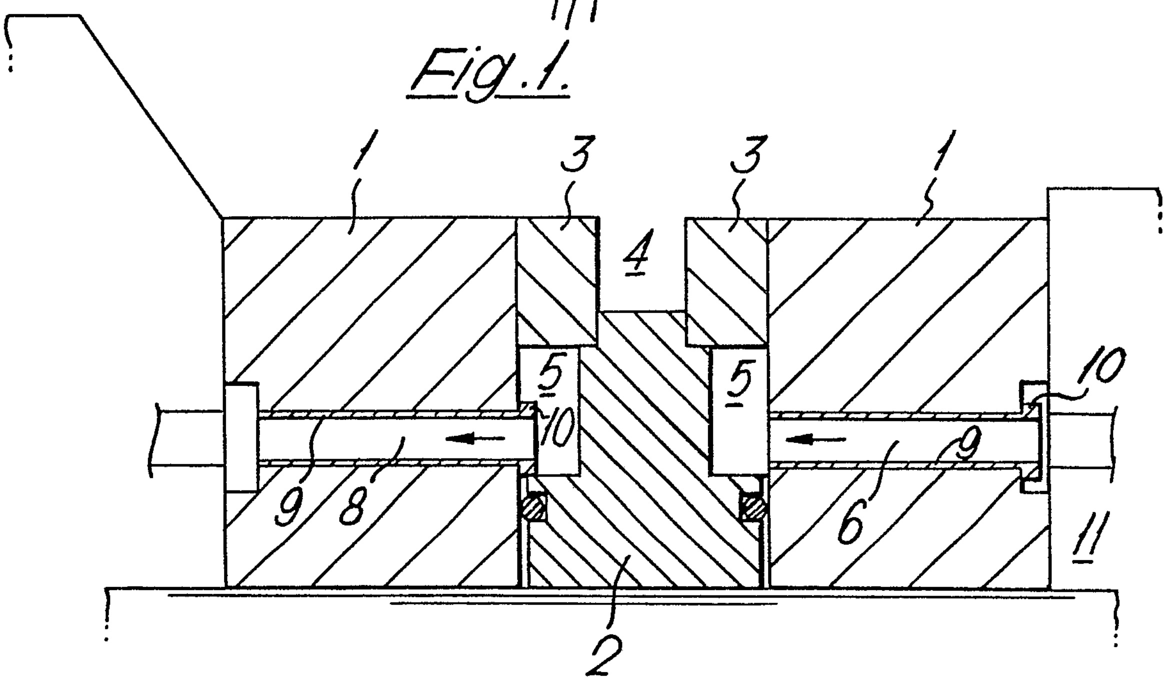

Fig.2.

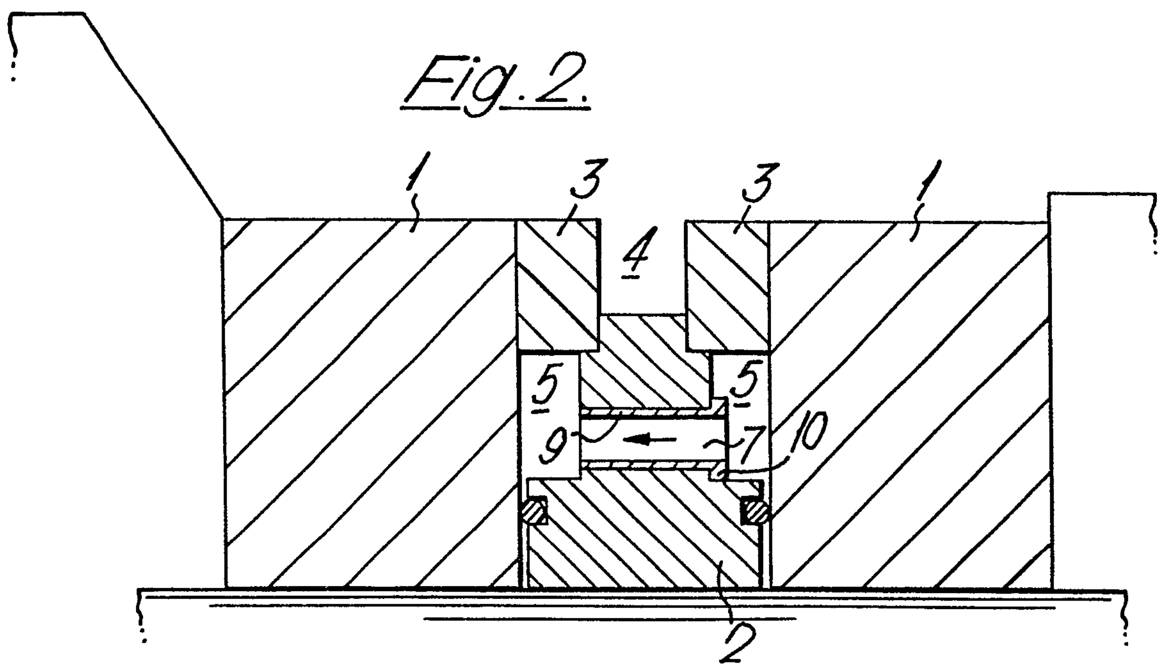

Fig.3.