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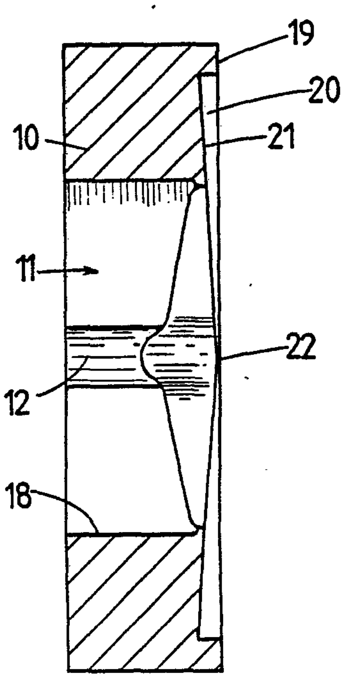
(54) Improvements in or relating to the forming of extrusion dies.

(57) In a method of forming an extrusion die by forming an extrusion aperture 11 in a die piece 10, forcing a flowable material 14 at least partly through the extrusion aperture so that the leading surface 16 of the material becomes deformed in the extrusion direction, and then reshaping the die piece in such a manner that the axial bearing depth of the extrusion aperture at any location around its periphery corresponds to the deformation of the leading surface of the flowable material at that location, as an additional step, before or after the reshaping, the axial bearing depth of the aperture 11, at locations around its periphery, is adjusted for example by machining one surface of the die piece, by amounts dependent on the distance of said locations from the centre of the die piece.



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"Improvements in or relating to the forming of extrusion dies"

The invention relates to the forming of extrusion dies, such as dies used for extruding aluminium.

It is well known that in an extrusion die which is of substantially constant axial bearing depth between the inlet and outlet, the resistance to the flow of material through the die varies in different parts of the die aperture in accordance with the shape of the aperture. For example, the resistance to flow between two opposed parallel walls will be generally inversely proportional to the spacing between the walls. In addition, the extruding pressure normally varies across the die aperture. These variations in the resistance to flow and extrusion pressure in different parts of the die aperture lead to different rates of flow in the material being extruded, leading in turn to severe internal stresses in the material. It is therefore advantageous to design an extrusion die so that the rate of flow of the material being extruded is substantially uniform over the whole area of the aperture.

It is known that the resistance to flow in any part of an extrusion die may be reduced by reducing the axial bearing depth of the aperture, or increased by increasing the bearing depth. It has accordingly, been the practice to design extrusion dies so that the bearing depth is reduced in areas where the shape of the aperture is such that the resistance to flow will be high, and/or where the extrusion pressure is low. Estimating the correct bearing length requires skill and experience on the part of the die designer. However, even a good designer is very unlikely to produce a die which will give satisfactory extrusion without proving trials and modifications and, in practice, it is normally necessary to test the die a number of times, making modifications to the bearing depth each time, before an acceptable design is achieved. This is obviously time consuming, and, at best can achieve only an approximate result.

In our European Patent Application No. 83302931.7 (Publication No. 0,095,359) there is described and claimed a simple method of determining, in an extrusion die, the bearing depth required in different parts of the die aperture to provide a substantially uniform rate of flow across the die aperture. In a particular method described in the afore-mentioned application, an extrusion aperture is formed in a die piece, for example by spark erosion, and a flowable material is then forced partly through the extrusion aperture so that the leading surface of the material becomes deformed in the extrusion direction. The surface within the extrusion aperture which remains exposed is then removed by chemical or electro etching, so that the effective axial bearing depth of the extrusion aperture at any location around its periphery is determined by the depth to which the flowable material extends into the aperture at that location. Since the extent to which the flowable material flows into the extrusion aperture is inversely proportional to the resistance to flow at that location, the axial bearing depth of the completed die at that location is also inversely proportional to the resistance to flow, so that when the die is subsequently used for extrusion, there is substantially uniform rate of flow over the whole of the die aperture.

The present invention provides improvements in the methods described and claimed in the above-mentioned European application.

As previously mentioned, the different rates of flow in a material being extruded through a die depend, to a certain extent, on the overall variation in extruding pressure across the die aperture, regardless of the shape of the die. It is found that, in some circumstances, the methods as described in the above-mentioned patent application may not fully compensate for this variation in overall extrusion pressure (known as the "macro flow profile") and it is an object of the present invention to provide an improvement in the methods whereby this variation may be more effectively compensated for.

Accordingly, the present invention provides a method of forming an extrusion die, of the kind comprising forming an extrusion aperture in a die piece, forcing a flowable material at least partly through the extrusion aperture so that the leading surface of the material becomes deformed in the extrusion direction, and then reshaping the die piece in such a manner that the axial bearing depth of the extrusion aperture at any location around its periphery corresponds to the deformation of the leading surface of the flowable material at that location, characterised by the additional step of adjusting the axial bearing depth at locations around the periphery of the extrusion aperture by amounts dependent on the distances of said locations from the centre of the die piece.

In one method according to the present invention, the adjustment is carried out, before the aforesaid reshaping of the die piece in accordance with the deformation of the flowable material, by profiling the inlet end of the die piece to reduce the axial thickness of the die piece by an amount which increases with distance from the centre of the die piece.

The inlet end of the die piece may be profiled by machining.

In an alternative method according to the invention, said adjustment may be carried out by applying across the inlet end of the die piece, before the step of forcing the flowable material at least partly through the extrusion aperture, an extension having an aperture which registers with the extrusion aperture of the die piece,which extension has an axial thickness which increases with distance from the centre of the die, so that when the flowable material is forced through the extension and at least partly through the extension aperture in the die piece, the axial extent to which the flowable material extends into the die piece is, at any location, reduced by the axial thickness of the extension at that location, the extension subsequently being removed from the die piece before it is used in an extrusion process.

The extension may comprise a preform which is applied to the die piece, or it may comprise a body which is cast _in situ_ on the die piece. In either case the extension may, for example, be formed from wax or synthetic plastics material.

In the case where the die piece is reshaped by a chemical etching or electro etching method, the extension may be left in contact with the die piece during the etching process so as to protect the inlet end face of the die piece.

In any of the above arrangements the adjustment in axial bearing length may vary linearly from the centre to the circumference of the die. For example, the ratio of axial bearing length reduction to distance from the centre of the die may be in the range 1:18 to 1:12.

The following is a detailed description of embodiments of the invention, by way of example, reference being made to the accompanying drawings in which:

Figure 1 is a diagrammatic representation of an extrusion die,

Figure 2 is a diagrammatic vertical section through the die of Figure 1,

Figures 3, 4 and 5 illustrate stages in the known method of forming the die,

Figure 6 is a diagrammatic vertical section through a die modified according to one embodiment of the present invention, and

Figures 7 to 8 illustrate stages in a further method of forming the die in accordance with the present invention.

Referring to Figure 1, the die piece 10 is formed with an extrusion aperture 11 comprising a central cylindrical portion 12 from which extend two narrower parallel-sided arm portions 13. It will appreciated that Figure 1 shows a very simple form of extrusion aperture for the purposes of illustration only and that the principles of the invention are applicable to extrusion apertures of any shape and complexity, including apertures for extruding hollow sections.

The dimensions of the aperture 11 are calculated in the usual way to allow for shrinkage and deflection of the die material during the extrusion process. The aperture will normally be electro-discharge machined in the die piece and then cleaned and polished.

As best seen in Figure 2, the die piece 10 is of constant axial thickness so that, initially, the extrusion aperture is of constant axial bearing depth.

In use of the die the resistance to flow in the cylindrical portion 12 of the aperture will be less than the resistance to flow between the closely adjacent side-walls of the arm portions 13. The resistance to flow at the outer ends of the arm portions 13 will be even greater due to frictional resistance of the end wall of each arm. Consequently material extruded through the die in the form shown in Figure 2 would be subjected to non-uniform flow leading to undesirable internal stresses. Figures 3 to 5 illustrate the known method, described in the above-mentioned European Patent Application No. 83302931.7 of adjusting the axial bearing depth of the die aperture so as to give substantially uniform flow.

Referring to Figure 3, a suitable flowable compound 14 is forced partly into the extrusion aperture 11 by means of a piston (not shown) which simulates the action of an extrusion press. A probe (not shown) is located within the aperture to detect and indicate when the compound has been injected into the aperture to a pre-determined extent, the piston then being stopped so that extrusion ceases when the compound reaches the probe.

As may be seen in Figure 3, due to varying resistance to flow in different parts of the die aperture, the leading surface of the compound 14 deforms in the axial direction, the part of the compound passing through the cylindrical portion 12 moving ahead of the part of the compound moving through the arm portions 13. Consequently, when the piston is stopped the peripheral edge of the leading surface of the compound contacts the interior surface of the aperture 12 along a shaped line 16 intermediate the inlet 17 and outlet 15 of the extrusion aperture.

In accordance with the basic method, the die is then reshaped, for example by subjecting it to an acid etching process or an electro-etching process so as to remove surface material from the interior of the extrusion aperture in the area between the line 16 and the outlet 15, as indicated at 18 in Figure 5. The compound 14 is preferably an acid resistant or electrically non-conductive material, as the case may be, so as to protect from etching the parts of the die aperture which the flowable material contacts. The exterior of the die also is coated or covered with an acid resistant or non-conductive material. Further details of the process are given in the above-mentioned European patent application.

Once the etching has been completed, as shown in Figure 5, the effective bearing portion of the die is now only that portion which was protected by the compound 14 and which is of varying axial bearing depth. Since the axial bearing depth has been automatically adjusted according to the rate of flow through the untreated die piece, flow will then be substantially uniform over the whole of the extrusion aperture, thus substantially reducing the internal stresses in extrusions produced by the die.

It is found that in some circumstances, however, the automatic adjustment of axial bearing depth by this method may not allow sufficiently for the variation in overall extruding pressure across the die aperture which occurs irrespective of the shape of the die. Thus, the overall extrusion pressure is greater at the centre of the die and decreases with increasing distance from the centre of the die. Figure 6 shows one method according to the present invention for compensating for this effect.

As may be seen from Figure 6, before the die aperture is reshaped by the method described above in relation to Figures 1 to 5, the inlet end face 19 of the die piece is machined to form a circular recess 20 the bottom wall 21 of which slopes in the extruding direction as it extends from the centre 22 of the die towards the outer periphery. The effect of machining the end face of the die in this fashion is to reduce the effective axial bearing depth of the die at each location around the periphery of the aperture by an amount which increases in proportion to the distance of the location from the centre 22 of the die. Thus, at the centre of the die, where the extrusion pressure is greatest, there is little or no reduction in the bearing depth whereas at the outer periphery of the die, where the extrusion pressure is less than it is at the centre, the bearing depth is reduced by a greater amount so as to provide a correspondingly greater reduction in the resistance to flow.

Thus, when the flowable compound 14 is forced against the inlet face of the die, the leading face of the compound, since it is essentially flat, passes first into the central portion of the die aperture, and only subsequently enters the outer portions of the die. Thus, after the injection of the compound partly through the die aperture has ceased, the extent to which the compound has projected into the aperture at any location is reduced by an amount equal to the axial depth of the recess 20 at that location. Since the recess 20 is of increasing depth towards the periphery of the die piece, the axial bearing depth is correspondingly reduced with distance from the centre of the die.

It will be appreciated that a similar effect might be achieved by machining a recess, similar to the recess 20, in the inlet face of the die piece shown in Figure 5, after the die piece has been shaped by the basic method. In this case, however, care is necessary to ensure that at no point does forming of the recess cut away the entire bearing depth of the die piece.

It is found in practice that the inclination of the bottom surface 21 of the recess 20 is preferably such that the ratio of reduction of axial bearing depth to distance from the centre of the die is in the range of 1:18 to 1:12. Although the sloping surface of the bottom of the recess is shown as linear, it may in some circumstances be curved.

Figures 7 to 9 illustrate an alternative method according to the invention.

By this method an extension 23 is applied to the inlet face 19 of the die piece 10 before the method of Figures 1 to 5 is carried out. The extension 23 is formed with an aperture 11a which registers exactly with the aperture 11 of the die piece. However, the rear surface 24 of the extension 23 is formed with a circular recess the axial depth of which decreases with distance from the centre line 22 of the die piece. The inclination of the bottom surface of the recess may be in the range of 1:18 to 1:12, as in the method of Figure 6.

The extension 23 may be preformed as a unit and then applied to the die piece 10, or it may be moulded in situ against the die piece 10. It may be formed from wax or synthetic plastics material or from any other suitable material.

After the extension 23 has been applied to the die piece 10, the compound 14 is forced through the aperture 11a in the extension 23 and partly into the extrusion aperture 11 in the die piece as shown in Figure 8. In this case, however, the extent to which the flowable compound 14 projects into the aperture in the die piece 10 at any location is reduced by an amount equal to the thickness of the extrusion 23 at that location. Since the extension 23 is of increasing

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thickness towards the periphery of the die piece, the reduction in the extent to which the compound projects into the die piece 10 is greater nearer the periphery.

When the compound 14 reaches the desired position, determined by a probe as described above, the surface material is removed from the interior of the die aperture 11 by electro etching or chemical etching or by any other suitable method as described in the above-mentioned European patent specification. During the etching the extension 23 may be maintained in contact with the surface 19 of the die piece so as to protect that surface from etching.

Once the removal of surface material from the interior of the extrusion aperture has been completed, the extension 23 is removed, as seen in Figure 9, and the die piece is ready for use.

The effect of applying the shaped extension 23 to the die piece during the die forming process is to superimpose on the variation in axial bearing depth provided by the basic method a further variation in bearing depth which is dependent solely on the variation in extrusion pressure across the die piece.

Both of the above described methods may result in a die piece where the axial bearing length of the extrusion aperture at each location is more closely correlated to the resistance to flow and extrusion pressure at that location, so as to result in more nearly uniform flow across the whole area of the extrusion aperture.

A suitable material for use as the flowable compound in the methods according to the invention is an acid resistant paste sold under the trade name Sericol 922. Using this material, after the paste has been partly extruded into the die, the die is baked to harden the paste. The exterior of the die is then protected with a lacquer and the die is then etched in aqua regia to remove the steel of the die piece from those areas of the aperture which are not contacted by the acid resistant paste. The Sericol 922 may subsequently be removed by sodium hydroxide solution, a solvent being used to strip the lacquer from the die.

A silica powder (for example that sold under the trade name Aerosil) may be added to the Sericol 922 to increase the viscosity of the paste.

An alternative flowable material which might be used is a resin of the kind which is cured by being subject to ultra violet light, such as the resin sold under the trade name UCB Resin T. Reaction setting resins may also be used.

Another material suitable for use as the flowable compound is a material conventionally used to simulate aluminium flow behaviour when testing extrusion dies. This material comprises a material sold under the trade name Filia Wax with the addition of 5% paraffin wax. This material may be used cold and has the advantage of being easy to handle and readily

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stripped from the die after etching.

CLAIMS

1. A method of forming an extrusion die comprising forming an extrusion aperture (11) in a die piece (10), forcing a flowable material (14) at least partly through the extrusion aperture so that the leading surface (16) of the material becomes deformed in the extrusion direction, and then reshaping the die piece in such a manner that the axial bearing depth of the extrusion aperture at any location around its periphery corresponds to the deformation of the leading surface (16) of the flowable material (14) at that location, characterised by the additional step of adjusting the axial bearing depth at locations around the periphery of the extrusion aperture (11) by amounts dependent on the distances of said locations from the centre of the die piece.

2. A method according to Claim 1, characterised in that said adjustment of the axial bearing depth is carried out by profiling the inlet end (19) of the die piece (10) to reduce the axial thickness of the die piece by an amount which increases with distance from the centre (22) of the die piece.

3. A method according to Claim 2, characterised in that the inlet end (19) of the die piece is profiled by machining.

4. A method according to any of Claims 1 to 3, characterised in that said additional step of adjusting the axial bearing depth is carried out before the aforesaid reshaping of the die piece (10) in accordance with the

deformation of the flowable material (14).

5. A method according to Claim 1, characterised in that said adjustment of the axial bearing depth is carried out by applying across the inlet end of the die piece (10) before the step of forcing the flowable material (14) at least partly through the extrusion aperture (11), an extension (23) having an aperture (11a) which registers with the extrusion aperture (11) of the die piece, which extension has an axial thickness which increases with distance from the centre (22) of the die, so that when the flowable material (14) is forced through the extension and at least partly through the extension aperture in the die piece, the axial extent to which the flowable material extends into the die piece is, at any location, reduced by the axial thickness of the extension at that location, the extension (23) subsequently being removed from the die piece (10) before it is used in an extrusion process.

6. A method according to Claim 5, characterised in that the extension comprises a preform (23) which is applied to the die piece, or comprises a body which is cast <u>in situ</u> on the die piece.

7. A method according to Claim 6, characterised in that the extension (23) is formed from wax or synthetic plastics material.

8. A method according to any of Claims 5 to 7, characterised in that the die piece (10) is reshaped by a chemical etching or electro etching method and the extension (23) is left in contact with the die piece during

the etching process so as to protect the inlet end face (19) of the die piece.

9. A method according to any of Claims 1 to 8, characterised in that the adjustment in axial bearing length varies linearly from the centre (22) to the circumference of the die (10).

10. A method according to Claim 9, characterised in that the ratio of axial bearing length reduction to distance from the centre of the die is in the range 1:18 to 1:12.

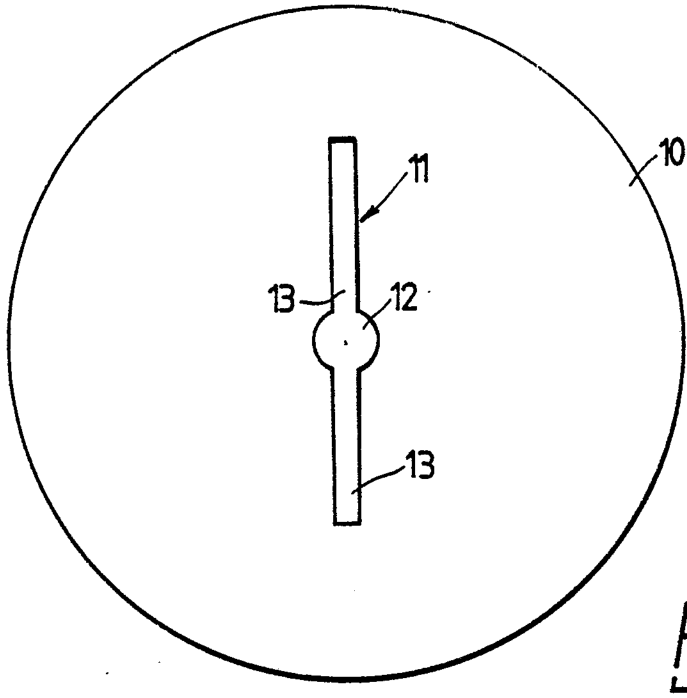

Fig.1.

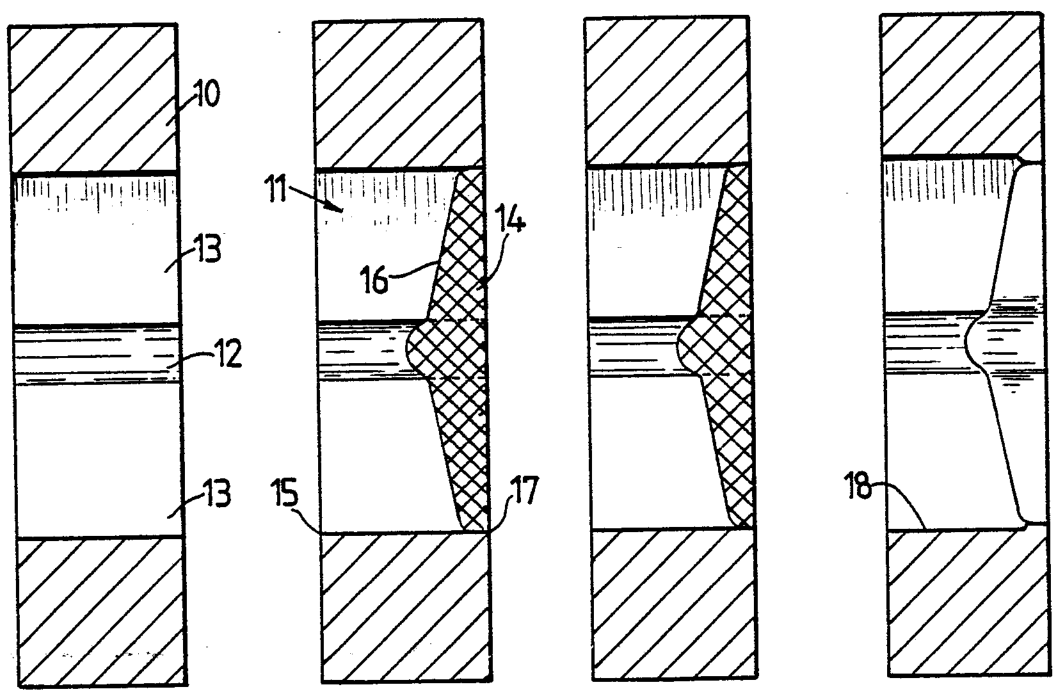

Fig.2. Fig.3. Fig.4. Fig.5.

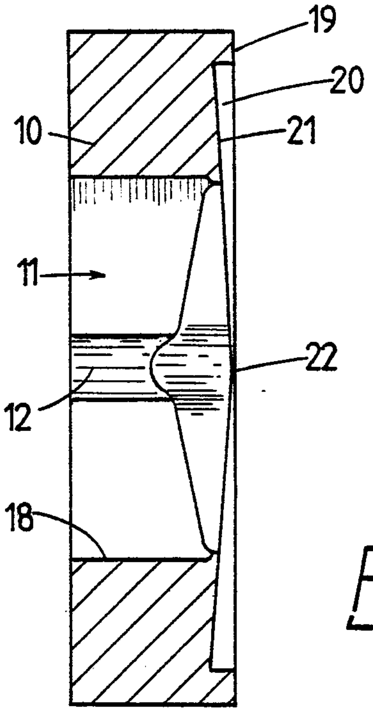

Fig. 6.

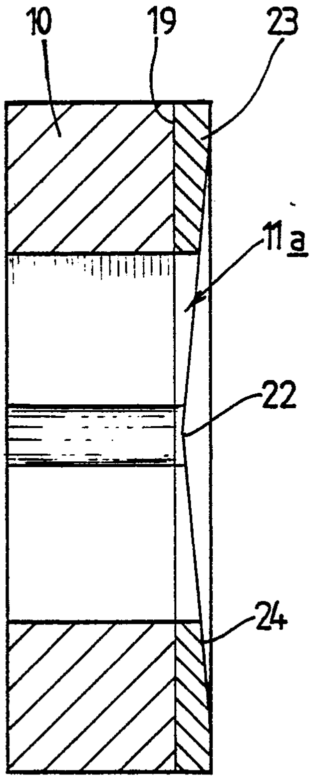

Fig.7.

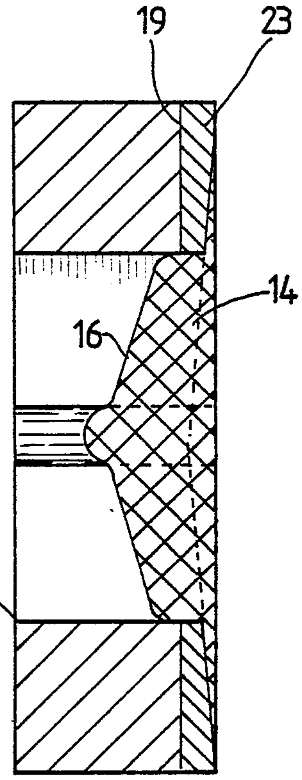

Fig.8.

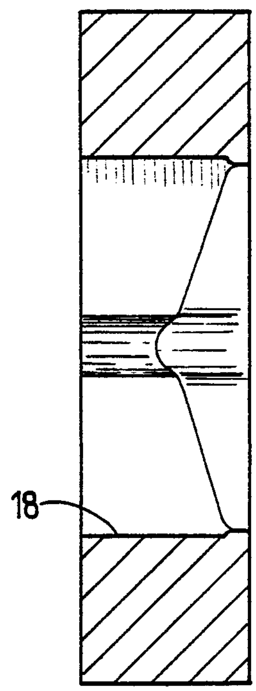

Fig.9.

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EUROPEAN SEARCH REPORT

Application number

EP 85301941.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y,D	EP - A3 - 0 095 359 (HOBSON) * Fig. 1-5 * --	1	B 21 C 25/10 B 30 B 11/22
Y	US - A - 2 833 406 (BILLEN) * Column 2, lines 28-30 * --	1	
A	DE - A1 - 2 748 392 (DEUTSCHE GOLD) * Totality * --	1	
A	US - A - 1 789 675 (ELIAS) * Fig. 4 * --		
A	DD - A - 126 764 (FAHRENSCHON) * Claim * --		TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	US - A - 4 187 443 (D'AMATO) * Fig. 3-6; claim 1 * ----		B 21 C B 23 P B 29 C B 30 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	01-07-1985	GLAUNACH

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document