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(54) Reinforced heat resisting member and production method.

(57) In a heat resisting aluminum alloy member with local metal matrix composite which contains inorganic fibers as reinforcing material, the matrix aluminum alloy of the metal matrix composite contains very little alloying elements in order to attain the highest heat shock resistance.

EP 0 447 701 A1

This invention relates generally to a heat resisting aluminum alloy member reinforced locally by inorganic fibers, and a productive method of the same, and particularly but not exclusively is applicable to a piston head, a cylinder head and the like of an internal combustion engine.

In general, if a repetition of thermal loads is locally exerted on a member of a structure, cracks are initiated in the member due to repetition of local compression stresses at a higher temperature area and local tension stresses at cooling phase of the area, so that the life of the member is shortened.

For example, in an internal combustion engine, the repetition of thermal loads is exerted on an aluminum alloy piston head, the space between valves of an aluminum alloy cylinder head and the like, and it has been proposed already to reinforce locally such portions by metal matrix composite which contains fibrous inorganic reinforcing material, such as a SiC-whisker or a silicon nitride whisker, so as to prolong the life of the aluminum alloy piston, etc. (for example, see Japanese Laid Open Patent No. 62-233456).

However, the thermal expansion coefficient of the reinforced portion becomes very small compared with that of non- reinforced body portion, so that a difference of thermal expansion coefficient at an interface between the reinforced portion and the non-reinforced body portion of the member will cause a high stress at the interface at higher temperatures and finally cracks are initiated in the interface under the repetition of thermal loads.

One effective means of escaping from such damage is to enlarge the reinforced portion to keep the interface away from the hottest zone, lest the interface should be exposed to high temperatures, but according to such means, the amount of the expensive inorganic fiber increases to make the reinforced portion, and as a result, the cost of the heat resisting member will be raised.

Accordingly, it is an object of the present invention to provide a heat resisting aluminum alloy member with local metal matrix composite on which cyclic thermal load can be applied,and a productive method of the same, wherein the likelihood of cracks arising under repetition of heat cycles is reduced, and the manufacturing cost is reduced.

Another object of the invention is to provide a heat resisting aluminum alloy member with local metal matrix composite and a productive method of the same, wherein the combination of a matrix and reinforcing material for the metal matrix composite is optimized so as to give the highest heat resistant property to the metal matrix composite, and thus, the components of the aluminum alloy matrix to form the metal matrix composite are generally different from those of the aluminum alloy matrix of the body portion of the heat resisting member.

In accordance with an aspect of this invention, a heat resisting member of aluminum alloy with local metal matrix composite which comprises inorganic fibers, the matrix aluminum alloy of the metal matrix composite contains Si, Cu, Ni and Mg at less than 1%; Fe and Mn, which exist as impurities, at less than 0.5%; and other impurities at less than 0.3%. Higher content of the above alloying elements will reduce the heat resistant property of the metal matrix composite containing fibrous material.

In preferred embodiment of this invention, a volumetric ratio of the inorganic fibers of the metal matrix composite lies within a range of 5 to 25%.

Moreover, in a production method of a heat resisting member with local metal matrix composite, the reinforcing materal in the metal matrix composite is inorganic fiber, and an aluminum alloy matrix reinforced by the inorganic fibers contains Si, Cu, Ni and Mg at less than 1%; Fe and Mn, which exist as impurities, at less than 0.5%; and other impurties at less than 0.3%, and the metal matrix composite is welded to the body portion of the heat resisting member so as to locally reinforce the heat resisting member.

The above, and other objects, features and advantages of this invention, will be apparent from the following detailed description of an illustrative embodiment thereof to be read in connection with the accompanying drawings, wherein like reference numerals identify the same or corresponding parts in the several views.

Figures 1 to 6 are explanatory drawings of a process to make a piston according to an embodiment of this invention;

Figures 7 is a graphical representation for a volumetric ratio - tensile strength relationship of the reinforced portion of the piston of Figure 6;

Figures 8 to 11 are explanatory drawings of a process to make a conventional piston; and

Figure 12 is a graphical representation of heat cycle - number of cracks relationships for the three kinds of pistons.

According to several test results to increase the heat shock resistance of metal matrix composites, alloying elements which are added to an aluminum alloy matrix to increase its strength exert rather an unfavorable influence upon crack initiation caused by cyclic thermal shocks, and inorganic fibers in the metal matrix composite produce a very good effect on the crack prevention. That is, when the alloying elements, such as Si, Cu, Ni, Mg and the like, exist at less than 1%, the elongation, at high temperatures, of the aluminum alloy is very improved. Further, it produces a good effect on the crack prevention if the

Referreing to the drawings and table, and initially to Figure 1, a preform 1 is made of Sic-whisker (manufactured by "Tokai-Carbon" Co, Ltd. and identified by "β-type whisker") so as to have a volumetric ratio V_f of 15%, and set in a metal mold 2. Then, molten pure aluminum of 99.7% is poured into the metal mold 2 as shown in Figure 2, and a pressure of 800kgf/cm^2 is applied on the molten aluminum to squeeze the melt into the fine cavities of the whisker preform (Fig. 3) to produce the metal matrix composite. The composite is machined to the form 3 in Fig. 4. Shown in Figure 7 is a relationships between V_f of reinforcing fiber in the metal matrix composite and the tensile strength of the metal matrix composite.

A piston body 4 to be reinforced by the metal matrix composite 3 is made of aluminum alloy (JIS:AC8A) by gravity casting, and in the piston body 4, a tapered portion 4b is provided on the outlet of the combustion chamber 4a as shown in Figure 5 to fit the metal matrix composite 3 therein. The metal matrix composite 3 is welded to the piston body 4 by electron beam welding (Figure 6).

A piston to be compared with the above piston is made by a conventional process. That is, a preform 11 is made of Sic-whisker (the same as that described above) so as to have a volumetric ratio V_f of 15%, and set in a metal mold 12 as shown in Figure 8. Then, molten aluminum alloy (JIS:AC8A) is poured into the metal mold 12 (Figure 9), and after the metal mold 12 is closed up tight as shown in aluminum alloy contains Fe and Mn, which exist as impurities, at less than 0.5%, and other impurities at less than 0.3%.

A metallic fiber, a carbon fiber, an alumina fiber, a boric alumina fiber or an alumina-silica fiber can be used as the fibrous inorganic material and whisker such as SiC, silicon nitride or boric alumina produces a better effect on the crack prevention. Further, the volumetric ratio of the inorganic fiber should be selected within a range of 5 to 25%, because heat resistant property is hardly improved if the volumetric ratio is at less than 5%, and if the volumetric ratio is at more than 25%, the thermal expansion coefficient of the metal matrix composite becomes too small, compared with that of the body member, so that cracks are easily initiated in an interface between the metal matrix composite and the body member alluminum alloy due to great difference of the coefficients of expansion between them.

A metal matrix composite is made of a inorganic fiber whose volumetric ratio is selected within the range of 5 to 25%, and an aluminum base metal which contains Si, Cu, Ni and Mg at less than 1%; Fe and Mn at less than 0.5%; and impurities at less than 0.3%, and thereafter, welded to the body portion of a heat resisting member by electron beam welding, friction welding or the like so as to obtain the partially reinforced heat resisting memebr. Thus, it is easy to make the body portion of the heat resisting member complicate in structure. Figure 10, the melt is squeezed into fine cavities of the whisker preform under a pressure of 800kgf/cm^2 to form local metal matrix composite on a piston head. Thereafter, the piston shown in Figure 11 is machined from the casting.

A thermal shock test is conducted to compare the piston of this invention with the conventional piston. The piston is exposed to alternate temperatures of 400 and 150°C, and the cycle is 12 seconds.

As shown in Figure 12, no crack is found in the piston of this invention even after repetition of 6000 heat cycles, but in the conventional piston and in a piston made of aluminum alloy AC8A only, cracks are found after repetition of 3000 cycles and 1000 cycles, respectively. Further, many cracks are initiated at the interface between the piston body and the outer periphery of the reinforced portion of the conventional piston, but in the piston of this invention, no crack is found at the above interface. It is noted that the lengths of the outer periphery and the inner periphery are 60^{mm} and 50^{mm}, respectively.

According to Table 1, the coefficient of expansion of the piston body is nearer to that of the reinforced portion of the piston of this invention than to that of the reinforced portion of the conventional piston. It seems a reason why the piston of this invention shows no crack at the interface between reinforced portion and the body portion.

Having described an illustrative embodiment of this invention with reference to the accompanying drawings, it is to be understood that the invention is not limited to that precise embodiment, and that various changes and modifications may be effected therein by one skilled in the art without departing from the scope or spirit of the invention as defined in the appended claims.

In the embodiment, the invention is applied to the piston of the internal combustion engine, but it is widely applicable to such members which are exposed to a cyclic local thermal load as to be locally exposed to the repetition of heat cycles. Further, in the embodiment, the composite material 3 is fixed to the piston body 4 by electron beam welding, but it can be fixed also by friction welding.

The matrix alloy of the reinforced portion contains only a small amount of alloying elements, which are added normally to aluminum alloy members but have negative effects on thermal shock resistance, in order to attain the best thermal shock resistance of the metal matrix composite which contains inorganic fibrous material as a reinforcing material. As silicon which reduces thermal expansion coefficient of aluminum alloys is not included in the reinforced portion of the heat resisting member, the thermal expansion coefficient of the reinforced portion increases, resulting in smaller difference of the coefficients of expansion between the body portion and the reinforced portion of the heat resisting member becomes, so that no crack is initiated in the interface between the body portion and the reinforced portion of the member.

Moreover, the composite material and the body portion of the heat resisting member are made separately, so that the body portion can be molded by gravity casting. Therefore, it is easy to reduce the manufacturing cost of the member.

Table 1 Coefficient of Expansion (x 10^{-6}/C°) within a Range of 20 to 300°C

Piston body, common to the two kinds of tested pistons, of aluminum alloy AC8A	22.3
Reinforced portion of the conventional piston	16.1
Reinforced portion of the piston of this invention	19.5

Claims

1. A heat resisting member of aluminum alloy, a part of which consists of metal matrix composite which contains inorganic fibers as reinforcing material, wherein the matrix aluminum alloy of the metal matrix composite contains Si, Cu, Ni and Mg at less than 1%; Fe and Mn, which exist as impurities, at less than 0.5%; and other impurities at less than 0.3%.

2. A heat resisting member according to claim 1, wherein a volumetric ratio of the inorganic fibers in the metal matrix composite lies within a range of 5 to 25%.

3. A productive method of a heat resisting member with local metal matrix composite, in which the reinforcing material in the metal matrix composite is an inorganic fiber and the matrix aluminum alloy of the metal matrix composite contains Si, Cu, Ni and Mg at less than 1%; Fe and Mn, which exist as impurities, at less than 0.5%; and other impurities at less than 0.3%, and the metal matrix composite is welded to a body portion of the heat resisting member so as to locally reinforce the heat resisting member.

4. A heat resisting member as claimed in claim 1 or 2 in the form of a piston or a cylinder head of an internal combustion engine.

FIG.1

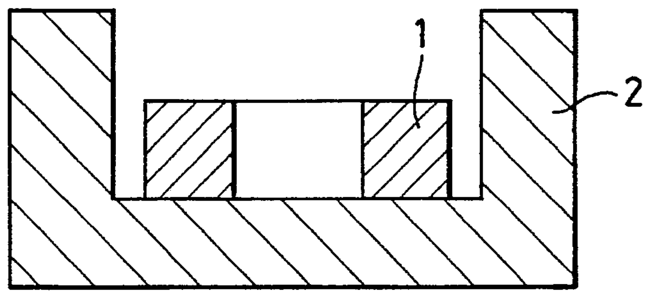


FIG.2

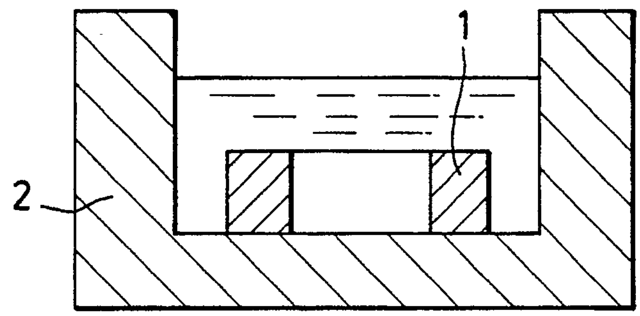


FIG.3

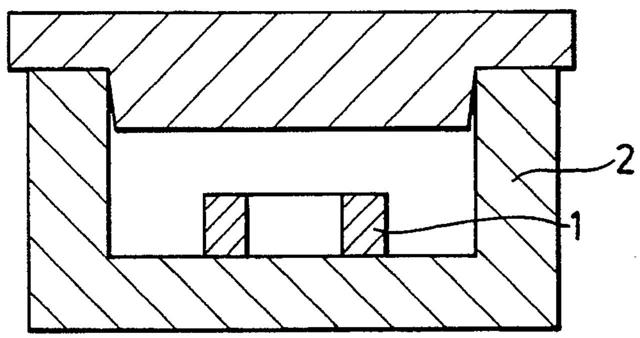


FIG. 5

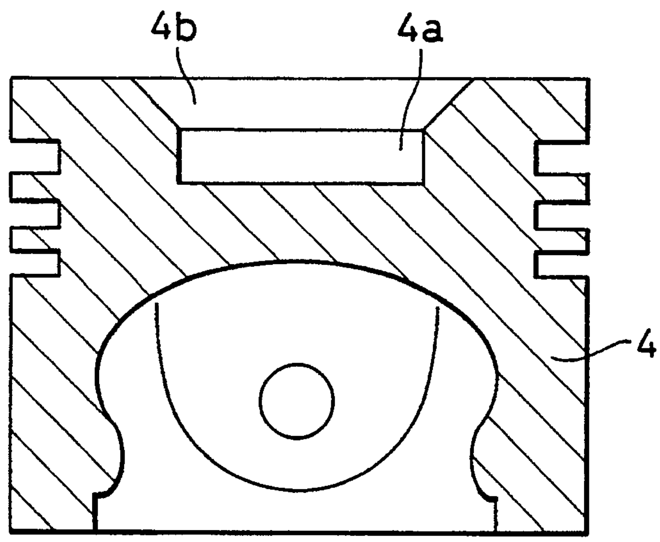


FIG. 4

FIG. 6

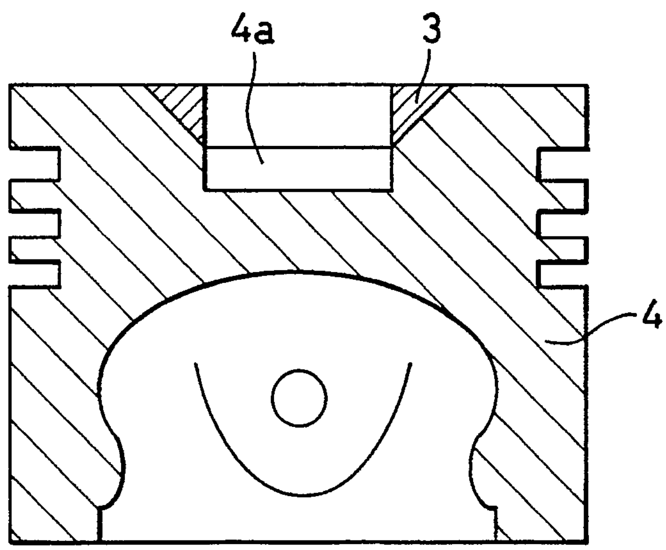


FIG. 7

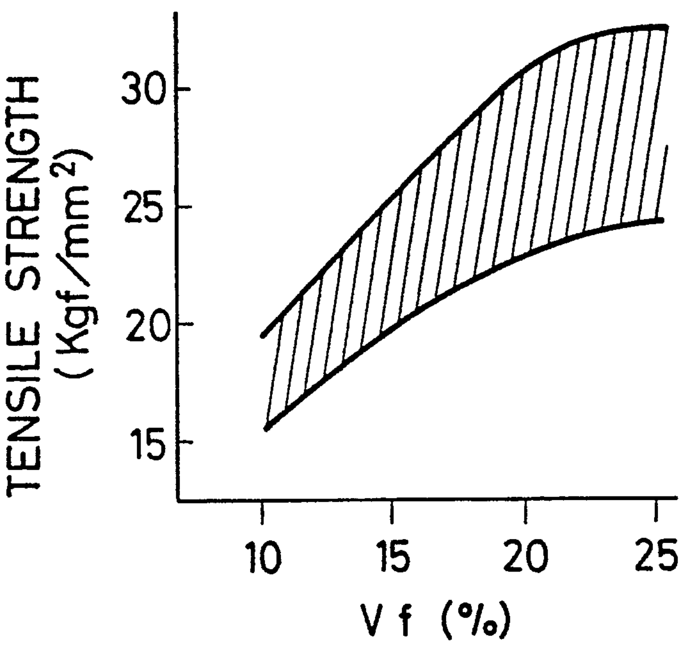


FIG. 8

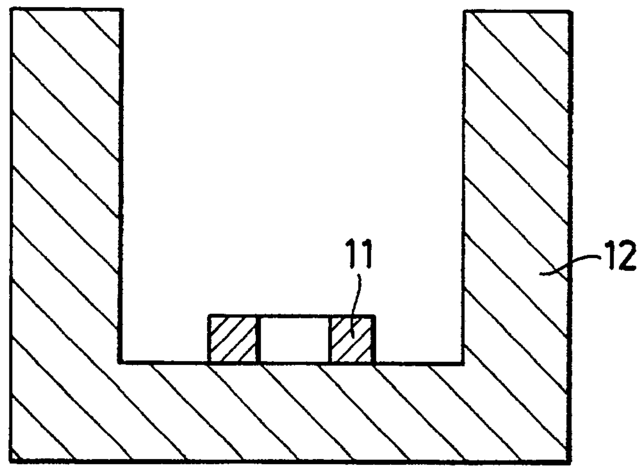


FIG. 9

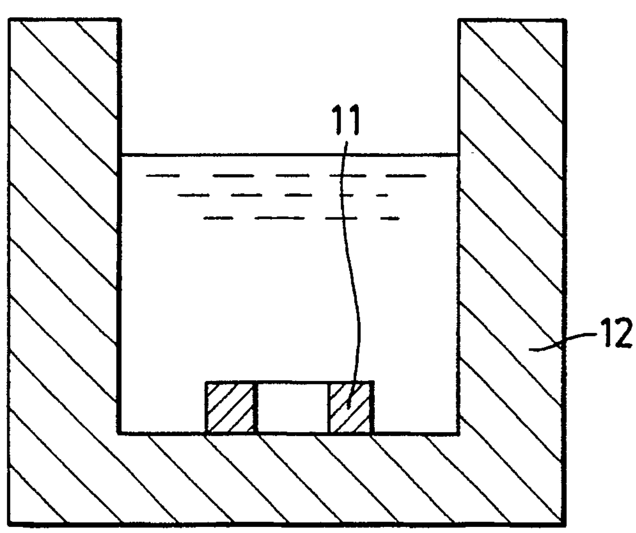


FIG.10

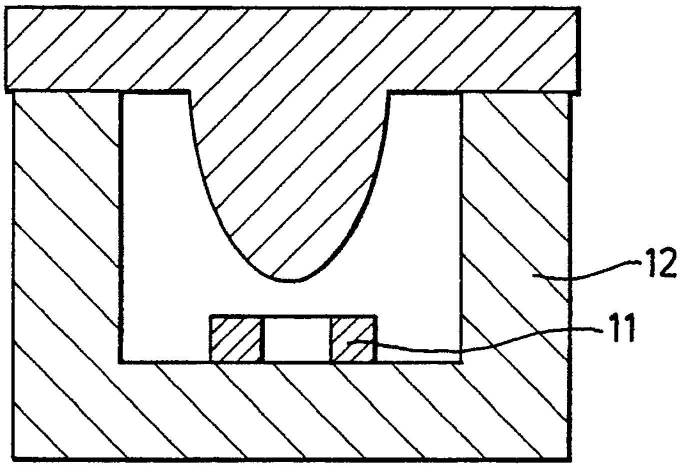


FIG.11

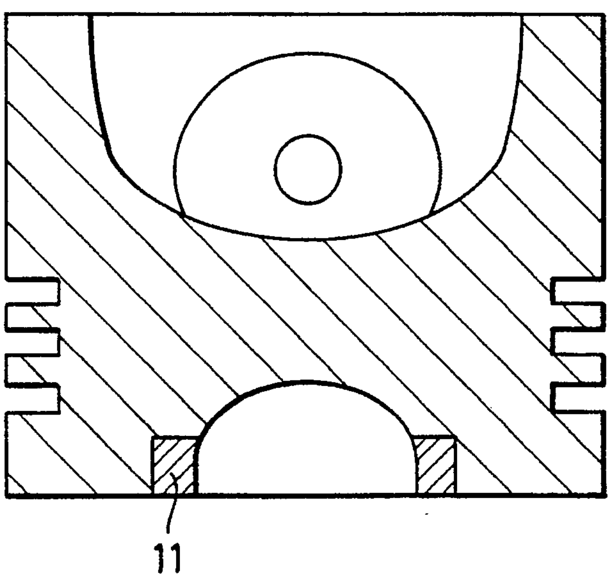
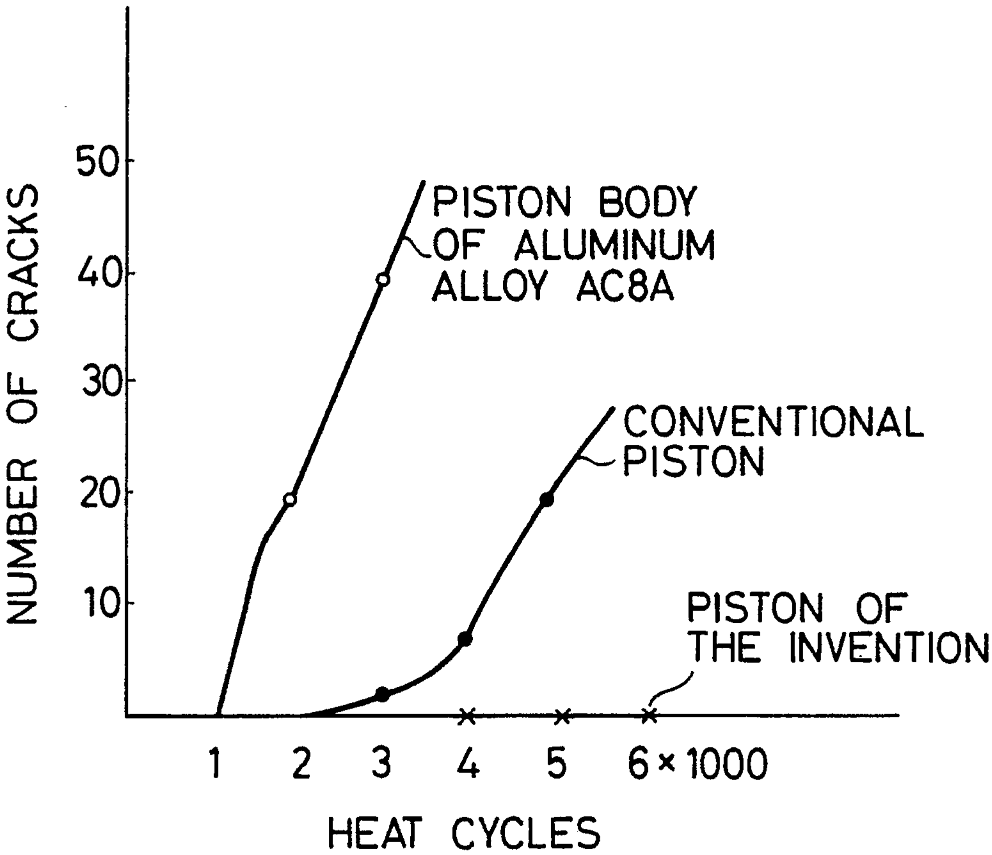


FIG.12


50
40
30
20
10
NUMBER OF CRACKS
PISTON BODY
OF ALUMINUM
ALLOY AC8A
CONVENTIONAL
PISTON
PISTON OF
THE INVENTION
1
2
3
4
5
6 × 1000
HEAT CYCLES

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 30 2967

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.5)
X Y	EP-A-0 170 396 (MITSUBISHI) * Pages 6-9; example 1, specimen 1,4 *	1-3 4	C 22 C 1/09 F 02 F 7/00
X Y	EP-A-0 106 108 (TOYOTA) * Claim 1; page 11, line 15 - page 18, line 11; page 23, table 1, examples 1,2 *	1-3 4	
Y	WPIL, FILE SUPPLIER, AN=89-295432, Derwent Publications Ltd, London, GB; & JP-A-1 216 167 (HONDA) 30-08-1989 * Whole abstract *	4	
Y	WPIL, FILE SUPPLIER, AN=89-295433, Derwent Publications Ltd, London, GB; & JP-A-1 216 168 (HONDA) 30-08-1989 * Whole abstract *	4	
A	DE-A-3 700 651 (KLÖCNKER-HUMBOLDT-DEUTZ) * Claim 6; column 2, line 61 - column 3, line 42 *		**TECHNICAL FIELDS SEARCHED (Int. Cl.5)** C 22 C F 02 F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21-11-1990	SCHRUERS H.J.

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EP 90 30 2967

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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DE-A- 3700651	21-07-88	None	

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82