Abstract: The two cylinder and piston systems (1, 3), operating in series, are driven by a crankshaft, with a minimum or even zero phase difference.
TWO-STAGE COMPRESSOR WITH TORQUE REDUCING CRANKSHAFT

DESCRIPTION

For the operation of two-stage compressors, with at least one cylinder and piston unit for preliminary compression and with a second cylinder and piston unit of smaller capacity for the second stage of compression, and similar machines, relatively very large peaks of torque occur during the cycle, making it necessary to have a high installed power (particularly with an electric motor) to ensure the regular operation of the machine. At the present time, use has been made of compressors having a large number of cylinder and piston systems to limit the peaks of torque (and of power), which entails high costs and large overall dimensions, as well as limited efficiency and difficult maintenance.

The object of the invention is to provide a simple machine, with a limited number of cylinder and piston systems operating in series (in practice, only two cylinder and piston systems operating in series), with the consequent advantages.

These and other objects and advantages will be made clear by the following text.

To achieve the objects indicated above, the invention relates to a machine such as a compressor of the two-stage type, with a pair of cylinder and piston systems operating in series and driven by a crankshaft, in which the two pistons are driven with a minimum phase difference, to reduce the peaks of torque.

Preferably, the two pistons are driven with a zero phase difference, so that the crankshaft can rotate equally well in one direction or in the opposite direction.

The invention also relates to a crankshaft for compressors and other equivalent machines, in which two cranks are positioned with a minimum or even a zero phase difference. Said shaft is to be appropriately balanced by the use of suitable counterweights.

The invention will be more clearly understood from the description and
the attached drawing, which shows a practical, non-restrictive example of the invention. In the drawing:

Fig. 1 shows a schematic view of the cylinder plane of a two-stage compressor according to the invention;

Fig. 2 shows in isolation the crankshaft of a compressor made according to the invention;

Fig. 3 shows an absorption diagram of a two-stage compressor of the conventional type; while

Fig. 4 shows an absorption diagram obtained with the device according to the invention.

Fig. 1 shows in a general way a diagram of a two-stage compressor, in which the number 1 indicates the cylinder of the first stage and 3 indicates the cylinder of the second stage. The intake chamber of the cylinder and piston system of the first stage is indicated by 5 and the compression chamber of said first stage is indicated by 7; this chamber 7 communicates with the intake chamber 9 of the second stage, the final compression chamber of the second stage being indicated by 10.

The pressure inside the crankcase and therefore under the pistons is kept equal to that of the chambers 7 and 9, since the crankcase itself communicates with the chamber 9.

The force that generates the torque is determined by the pressure difference between the upper and the lower surfaces of the pistons of both the first and the second stage. In the case of the first stage, this difference is negative (the pressure on the top of the piston is lower than that on the bottom) during the first part of the compression phase.

In a conventional compressor of this type, the two cylinder and piston systems 1, 3 are designed to operate in counter-phase and therefore with a crankshaft with a phase difference of 180° between its two crankpins. In a known arrangement of this kind, therefore, the variation of the diagram of the torque required from the motor for driving the crankshaft is illustrated in the graph in Fig. 3, where the degrees of the cycle of rotation of the shaft are shown on the horizontal axis and the torque in kgxcm is shown on the vertical
axis; in the said graph in Fig. 3, the curve A indicates the absorption due to
the compression torque of the first stage for obtaining the intermediate
pressure of the fluid. The straight section B parallel to the horizontal axis
corresponds to the opening of the compression valve of the first stage. The
second part of the cycle, represented by the curves C and D and by the cusp
E, shows the overall variation in said second stage which corresponds to the
sum of the torques due to the compression of the second stage, indicated by
the line F, and to the intake of the first stage which is indicated by G; the
intake of the second stage does essentially not require any torque, because of
the equivalence between the two opposing forces acting on the piston. An
examination of this graph in Fig. 3 shows clearly that a relatively very high
peak of torque E appears in the graph which is illustrated.

According to the invention, the machine in question is provided with a
crankshaft of the type illustrated in Fig. 2, in which the two crankpins 12 and
14 are exactly in phase with each other and are suitably balanced by
counterweights such as those indicated by 12A and 14A, in addition to the
flywheel 16 in an intermediate position between the two crankpins 12 and 14.
With this driving shaft the two cylinder and piston systems are exactly in
phase; it has been found that the graph of the torque present in a situation of
this kind is that shown in Fig. 4, in which the curve K relates to the intake of
the first stage, the curve L relates to the compression in the first stage, and
the curve M relates to the compression of the second stage, while the intake
of the second stage is practically free of force and consequently of torque,
owing to the compensating effect of the pressures acting in opposite
directions on the piston. The sum of the torques is therefore that indicated by
the curve N, with a peak P whose size is much smaller with respect to that
found at E in the conventional solution whose diagram is shown in Fig. 3.

To obtain an essentially balanced system, appropriate counterweights
such as those indicated by 12A and 14A will be provided, and a suitable
flywheel 16 will be provided between the two crankpins 12 and 14.
The aforementioned advantages are obtained with this arrangement.
It should be understood that the drawing shows only an example
provided solely as a practical demonstration of the invention, said invention being variable in its forms and arrangements without thereby departing from the scope of the guiding principle of the invention. The presence of any reference numbers in the attached claims has the purpose of facilitating the reading of the claims with reference to the description and to the drawing, and does not limit the scope of protection represented by the claims.
CLAIMS

1. A compressor of the two-stage type, or similar machine, with a pair of cylinder and piston systems operating in series and driven by a crankshaft, characterized in that the two pistons are driven with a minimum phase difference, to reduce the peaks of torque.

2. Compressor as claimed in claim 1, characterized in that the two pistons are driven with a zero phase difference, so that rotation can take place equally well in one direction or in the opposite direction.

3. Compressor as described and illustrated.

4. A crankshaft for a compressor with two cylinder and piston systems operating in series, or for a similar machine, characterized in that the two crankpins for the two pistons are essentially in phase with each other.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F04B25/00 F04B39/00 F04B27/00

According to international Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F04B F01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO–Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>X</td>
<td>FR 2 376 946 A (PEUGEOT) 4 August 1978 (1978-08-04) page 2, line 20 - line 29</td>
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<tr>
<td></td>
<td>figure 1</td>
<td>1,2</td>
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<tr>
<td>X</td>
<td>US 5 044 333 A (FUCHIGAMI WATARU ET AL) 3 September 1991 (1991-09-03) abstract</td>
<td>4</td>
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<tr>
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<td>column 2, line 15 - line 33 figure 1</td>
<td>1,2</td>
</tr>
<tr>
<td>A</td>
<td>DE 571 940 C (DAUBRON) 16 February 1933 (1933-02-16) page 1, line 39 - page 2,</td>
<td>1,2</td>
</tr>
<tr>
<td></td>
<td>line 63 figures</td>
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Date of the actual completion of the international search: 11 October 2000

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<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
</table>
| A        | US 2 405 475 A (RAYMOND GENTIL)  
6 August 1946 (1946-08-06)  
column 3, line 37 - line 45  
figure 11 | 1,4 |
| A        | US 1 905 747 A (PETERS ARTHUR E)  
25 April 1933 (1933-04-25)  
pages 1, line 32 - line 99  
figures 1,2 | 1,4 |
| A        | FR 1 113 243 A (COMPAGNIE DES FREINS ET  
SIGNAUX WESTINGHOUSE)  
26 March 1956 (1956-03-26)  
pages 2, column 1, paragraph 4 - page 3,  
column 2  
figures | 1 |
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR 2376946 A</td>
<td>04-08-1978</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>DE 571940 C</td>
<td></td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>US 2405475 A</td>
<td>06-08-1946</td>
<td>NONE</td>
<td></td>
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<tr>
<td>US 1905747 A</td>
<td>25-04-1933</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>FR 1113243 A</td>
<td>26-03-1956</td>
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