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Datasheet for the decision of 26 June 2008

Case Number: T 0076/07 - 3.2.04

Application Number: 96905008.7

Publication Number: 0886070

IPC: F04D 29/44

Language of the proceedings: EN

Title of invention:
Centrifugal compressor and diffuser for the centrifugal compressor

Patentee:
Hitachi, Ltd.

Opponent:
SIEMENS AKTIENGESELLSCHAFT

Headword:
-

Relevant legal provisions:
EPC Art. 56

Relevant legal provisions (EPC 1973):
-

Keyword:
"Inventive step (no)"

Decisions cited:
-

Catchword:
-

Case Number: T 0076/07 **-** 3.2.04

D E C I S I O N
of the Technical Board of Appeal 3.2.04
of 26 June 2008

Appellant: (Opponent)
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Decision under appeal:
Interlocutory decision of the Opposition Division of the European Patent Office posted 15 November 2006 concerning maintenance of European patent No. 0886070 in amended form.

Composition of the Board:

Chairman: M. Ceyte
Members: A. de Vries
T. Bokor

Summary of Facts and Submissions

I. The Appellant (Opponent) lodged an appeal, received 12 January 2007, against the interlocutory decision of the Opposition Division posted 15 November 2006 on the amended form in which the Patent No. EP-B-0886070 can be maintained, and simultaneously paid the appeal fee. The statement setting out the grounds was received 15 March 2007.

II. Opposition was filed against the patent as a whole and based on Article 100(a) together with Articles 52(1) and 54 EPC 1973 for lack of novelty, and together with Article 52(1) and 56 EPC 1973 for lack of inventive step.

The Opposition Division held that the grounds for opposition mentioned in Article 100 EPC 1973 did not prejudice the maintenance of patent as amended having regard to the following documents in particular:

E1: C. Osborne e.a., "The Application of Low Solidity Diffusers in Centrifugal Compressors", "Flows in Non-Rotating Turbomachinery Components", presented at the Winter Annual Meeting of the American Society of Mechanical Engineers, Chicago (IL), November 27-December 2 1988, ed. U. Rohatgi e.a., FED Vol.69, 89-101

E4: EP-A-0 402 870

In the appeal the following further document submitted by the Appellant played a role:

E11: N.A. Cumpsty, "Compressor Aerodynamics", Longman Scientific & Technical, Harlow, UK, 1989, pp 2,3,132-137

III. The Appellant requests that the decision under appeal be set aside and the patent be revoked in its entirety.

The Respondent requests that the appeal be dismissed and the patent be maintained as amended.

IV. Oral proceedings requested by both parties were held on 26 June 2008.

V. The wording of amended claim 1 held allowable by the opposition division is as follows :

"A centrifugal compressor comprising a rotation shaft (8), an impeller (1a-1e) mounted on said rotation shaft (8), and a first vaned diffuser (2a-2e) provided radially outwardly of said impeller (1a-1e) and having two opposed wall surfaces and a plurality of first vanes (2z) disposed between said wall surfaces in a spaced relationship to each other in a circumferential direction;
wherein a second vaneless diffuser (3a-3e) is provided at a downstream side of said first vaned diffuser (2a-2e),
said second diffuser (3a-3e) having two opposed wall surfaces (31,32;33,34;35,36;37;39;41,42;46,47) the axial distance therebetween being decreased progressively from an inlet to an outlet,
said first vanes (2z) of said first vaned diffuser (2a-2e) are so short that a line perpendicular to an inlet angle of the diffuser vane (2z) does not intersect the

adjoining vane (2z), and a value, obtained by dividing the average value of the pitch of the diffuser vane inlets and the pitch of the diffuser vane outlets by the chord length of the diffuser vane is not more than about 1,
characterized in that
the axial height (b2) of the outlet of said vaneless diffuser (3a-3e) is 0.3 to 0.6 times as large as the axial height (b1) of the outlet of said first vaned diffuser (2a-2e), and
- the inlet vane angle of said first vanes (2z) of said first vaned diffuser (2a-2e), measured in the peripheral direction of said first vanes (2z) of said first vaned diffuser (2a-2e), is 4° to 12° and [sic]"

VI. The Appellant argued as follows:

With respect to E1 the sole differences reside in the two ranges. Each is the result of routine experimentation on the part of the skilled person, a flow technician.

E1 already teaches pinching the vaneless diffuser to reduce rotation stalls. Though it does not include specific pinch ratios it includes clear prompts to determine suitable values by routine testing. In any case, the range of values for the "pinch ratio" covers a large part of the practicable pinch range, and corresponds closely to that already taught in E4.

Using E11 the values for inlet angle are seen to correspond to stagger angle values, which are not far removed from the values indicated in E1. Alternatively, the term "inlet vane angle" is unclear, and the corresponding feature has no limiting effect in the claim. No special effect, synergetic or otherwise, is associated with this feature.

VII. The Respondent argued as follows:

The invention's main objective resides in providing a low specific speed centrifugal compressor operating at high efficiency within a broad operation range. High efficiency results in particular from the shallower than usual vane angles employed for the low density diffuser. These values clearly lie well outside the range shown in E1. Such shallow angles, however, will normally give rise to high levels of turbulence in the area beyond the diffuser. This turbulence is suppressed by appropriately pinching the vaneless diffuser, which forces air flow at a steeper angle across the diffuser walls. Herein lies the invention's synergetic effect, in that pinching at the specified values allows much shallower vane angles in the vaned diffuser stage.

The pinch ratios known from E4 are not applicable in the present case, as in E4 the pinched diffuser follows a vaneless diffuser stage. The flow will therefore be essentially different to that in the present case. The lower limit, finally, is a result of the inventor's recognition that too much pinch gives rise to high friction losses in the channel downstream of the diffusers.

Reasons for the Decision

1. The appeal is admissible. Moreover it is allowable for the reasons indicated below.

2. *Background of the Invention*

The invention concerns a centrifugal compressor in which a first vaned diffuser is configured at the impeller outlet followed by a pinched or throttled diffuser. The vaned diffuser is a so-called low density diffuser, with widely spaced vanes and which at low specific speeds gives high performance within a wide operation range. The pinched diffuser acts to prevent stalling beyond the vaned region by appropriately adjusting the flow angle of fluid exiting the vaned diffuser.

3. *Inventive Step*

3.1 Closest prior art

It is common ground that E1 represents the closest prior art. E1 is a scientific paper on the application of low solidity diffusers or LSDs in centrifugal compressors. The second and third paragraphs of page 98 in conjunction with figure 23, option (C), in particular, describe a centrifugal compressor provided with a LSD, which is pinched or contracted in the vaneless downstream region. As acknowledged by all parties, this corresponds to the features of the preamble of claim 1 in the amended form found allowable in the decision under appeal.

E1, which is particularly concerned with establishing the design criteria and procedures of application of LSDs in centrifugal compressors (see abstract, last paragraph), moroever also mentions stagger angle, which is related to inlet vane angle, as an important such design criterion. In the section headed Senoo, 1984 (REF.5), see in particular figure 12 and the two immediately following paragraphs, the influence of stagger angle on performance (flow rate Cp) is discussed. Similarly, in section 3.2, where the authors discuss their own research, on page 95, second paragraph, "the sensitivity of performance to setting angle" or stagger angle is again specifically mentioned as a subject of study. Table I on page 99, finally, which contrasts the ranges of design variables used in the author's research against those of Senoo, again also includes stagger angle.

3.2 Differences with respect to the prior art

3.2.1 Both parties are also in agreement that the subject-matter of amended claim 1 as found allowable differs from E1 in its characterizing features, namely in the range of 0.3 to 0.6 for the ratio of axial height at the outlet of the vaneless diffuser to that at the outlet of the vaned diffuser (referred to hereinafter as "pinch ratio" by the Board), and in the range of inlet vane angles between 4° and 12°.

3.2.2 As regards the second of the ranges, the Board firstly notes that the term "inlet vane angle" does not represent recognized usage and is only understood in reference to the description. The paragraph bridging pages 14 and 15 referring to figure 3 appears the most relevant in this regard. It relates to a "mounting angle" α of the vane 2z, shown in figure 3. From its specific range, which is identical to that claimed, and the fact that no other angles are mentioned in the description, it may be safely assumed that "mounting angle" is synonymous to "inlet vane angle" in claim 1. Figure 3 shows this "mounting angle" α as between the chord line of a vane 2z (the line connecting its two end points) and what appears to be a ***curved*** circumferential line segment on which the vane is located, which on its own would lead to indeterminacy in the value of α. However, the original disclosure in original claim 4, and on page 9, lines 2 and 3, requires that the inlet vane angle is "measured in the peripheral direction of said first vanes (2z)", respectively, "measured in a peripheral direction". The Board considers these passages to constitute sufficiently clear instructions (albeit in somewhat awkward technical English) for the skilled person, using his common knowledge of geometry, and in conjunction with figure 3 to understand that the angle is to be taken with respect to the direction of the circumference at the locus of the vane, i.e. with respect to the tangential to the circumference at the vane locus. "Inlet vane angle" is thus understood to mean the angle between the vane chord line and the tangent at the locus of the vane on the circumference.

3.2.3 This "inlet vane angle" can be related to the "stagger angle" ξ mentioned throughout E1, and for which specific values appear in Table I on page 99. Using E11 (Cumpsty), which shows "stagger ξ" (page 135) in figure 4.1 as the angle between vane chord line and the perpendicular to the "peripheral direction", "inlet vane angle" α and "stagger angle" ξ can be related by α = 90°- ξ. The stagger angles mentioned in the right hand column of table I on page 99, namely 53° to 73°, then correspond to an inlet vane angle range of 17° to 37°.

E1 does not give any particular indication of the amount of pinch or contraction necessary for stall suppression.

3.3 Problem to be solved

3.3.1 As filed description page 14, lines 14 to 24, links the particular range of inlet vane angles to enhanced compressor performance. Thus, noting again that "mounting angle" is synonymous to "inlet vane angle", this passage indicates that "in a compressor of low specific speed ... the performance is enhanced by reducing a discharge angle of an impeller". To do so, it is proposed to "reduce an angle α of mounting of the vanes of the diffuser to 4° to 12°".

3.3.2 Pinching of the downstream passage on the other hand serves to suppress rotation stall as follows from as filed description page 14, line 23, to page 15, line 9, read in context with the immediately following paragraph of page 15. Thus when "mounting angle α [i.e. the inlet vane angle] is less than 12°... flow becomes unstable ..., so that rotation stall is liable to occur". By "progressively decreasing the passage height of the vaneless diffuser portion 3 [immediately downstream of vaned diffuser portion 2 in figure 2] "flow angle is larger ..., and the rotating stall can be suppressed".

The particular ratios can then be seen as securing this effect for the particular range of inlet vane angles (the lower limit serves to limit friction losses in the subsequent channel, see description page 16, lines 2 to 6).

3.3.3 E1 already teaches stagger angle (related to inlet vane angle as seen above) as a factor in influencing the enhanced performance of an LSD, as well as the use of pinch to suppress stall. The particular ranges - the only differences with respect to E1 - specify the conditions under which performance is optimally enhanced and stall prevented. The objective technical problem can be formulated accordingly as how to further optimize the design of a LSD in a centrifugal compressor with downstream pinching, such that performance is enhanced and stall is suppressed.

3.4 Obvious solution

3.4.1 The Board notes firstly that the main aim of E1 is "to establish application ranges and design criteria and procedures for LSDs", seen as particularly promising due to their enhanced performance and wide flow range, but for which limited data exist (see final paragraph of its abstract). An important theme throughout the paper is the absence of firm design criteria for LSDs, see for example section 1.2, final sentence; section 3.2, first sentence; or section 5.1, first sentence. Though it reviews the limited data available and then presents its own tentative results, the paper is clearly open-ended. It concludes, see section 6 "Conclusions", that "continued development work ... [is]

required ... to firmly establish design criteria and procedures".

3.4.2 From E1 the skilled person therefore learns, firstly, that LSDs enhance performance when applied to centrifugal compressors but that firm design criteria do not yet exist. However, he is taught that a number of specific factors, particularly stagger angle, influence performance. He is further explicitly told that further continued development is necessary.

3.4.3 It therefore stands to reason that the skilled person, a research engineer involved in the design and development of centrifugal compressors, prompted by E1 will continue development of design criteria of compressors with LSDs in the directions marked out by E1. For example, starting from the configuration shown in figure 23(C), with pinching in the region downstream of the LSD, he will subject that configuration to routine testing procedure and vary stagger angle in order to determine values for which LSD performance is optimally enhanced. In so doing he will not feel constrained to remain within the stagger angle range mentioned in table I of E1, which he understands to be first initial attempts at continued development that are tentative but in no way limiting on what is feasible. He will thus venture beyond this range, for example into the range of angles beyond 73°.

3.4.4 In so doing he remains aware of the deleterious effects of stall as described on page 98 of E1, and the need to simultaneously adjust the amount of pinching "until a reasonable flow angle [is] obtained, (i.e. below the stall criteria)" (E1, page 98, second paragraph, final sentence). For each variation of stagger angle he will thus verify the amount of pinch required for stall prevention. Initially, he may to this end take guidance from pinch amounts known to him from similar prior art such as E4, see page 2, lines 44 to 46, which (for a centrifugal compressor with vaneless diffuser) indicates pinching in a range of 0.375 to 0.75. This routine process of concurrent optimization with respect to two parameters, will ultimately lead him to stagger angles within the range corresponding (via the above simple relationship) to the inlet vane angle of claim 1, and pinch ratios within the corresponding range of claim 1 without the exercise of inventive skills. That this pinch ratio range then overlaps significantly with that of E4 further supports this finding. The resultant centrifugal compressor which falls within the scope of amended claim 1 thus lacks inventive step as required by Article 56 EPC 1973.

3.4.5 The Board has no reason to believe that the effect of enhanced performance for the claimed range of inlet vane angles is in any way surprising. As noted LSDs are per se associated with enhanced performance (and wide flow rate) when used in centrifugal compressors, and stagger angle is a known factor influencing that performance. Nor is any indication of a particular level of enhancement that might deserve the qualification "surprising" apparent, either from the original disclosure or the Respondent's submissions to date.

3.4.6 Similarly, the Board is equally unconvinced that there exists a synergy in the fact that the low inlet vane angles with enhanced performance are made possible by the selected pinch ratios. Firstly, this argument presumes the skilled person would not consider such low inlet vane angles (or conversely such high stagger angles) when departing from E1. As discussed above E1 is entirely open-ended, and expressly urges further development of design criteria, one of which is stagger angle. He is thus not constrained by the tentative examples of E1. Moreover, rather than that the two ranges provide an effect over and above the sum of their associated known effects, they merely provide those effects in a different balance determined in a completely foreseeable manner by their concurrent optimization.

3.4.7 Finally, the fact that the claimed range sets a lower limit on pinch ratio due to drawbacks not previously identified (here friction losses in the following passage), does not by itself render the entire range inventive. Inventiveness of the entire range hinges on the question of whether the skilled person departing from the prior art would seriously contemplate operating within the range. The Board holds that he would.

4. The Board concludes from the above that taking into account the amendments to claim 1 the patent and the invention to which it relates do not meet the requirements of the EPC.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The patent is revoked.

The Registrar The Chairman

G. Magouliotis M. Ceyte