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Datasheet for the decision of 10 February 2022

Case Number: T 0356/18 - 3.5.02

Application Number: 04255214.1

Publication Number: 1511164

IPC: H02K41/03

Language of the proceedings: EN

Title of invention:
Linear motor with reduced cogging force

Patent Proprietor:
Sanyo Denki Co., Ltd.

Opponent:
Siemens Aktiengesellschaft

Relevant legal provisions:
EPC Art. 56

Keyword:
Inventive step - (no)

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Case Number: T 0356/18 - 3.5.02

D E C I S I O N
of Technical Board of Appeal 3.5.02
of 10 February 2022

Appellant: (Opponent)	Siemens Aktiengesellschaft Werner-von-Siemens-Straße 1 80333 München (DE)
Respondent: (Patent Proprietor)	Sanyo Denki Co., Ltd. 15-1, 1-chome, Kitaotsuka, Toshima-ku Tokyo (JP)
Representative:	Wilson Gunn Blackfriars House The Parsonage 5th Floor Manchester M3 2JA (GB)
Decision under appeal:	**Decision of the Opposition Division of the European Patent Office posted on 8 December 2017 rejecting the opposition filed against European patent No. 1511164 pursuant to Article 101(2) EPC.**

Composition of the Board:

Chairman	R. Lord
Members:	G. Flyng
	J. Hoppe

Summary of Facts and Submissions

I. The opponent is appealing against the decision of the opposition division rejecting the opposition against the European patent EP 1 511 164.

II. Claim 1 of the patent as granted reads as follows:

"1. A linear motor which has a stator (1) and a movable element (3) constructed to reciprocate linearly relative to said stator (1), said linear motor comprises:

one or more magnetic pole rows (7) provided at one of said stator (1) and said movable element (3) and constituted by juxtaposedly arranging a plurality of permanent magnets (7A, 7B)

and an armature (9, 11) provided at the other of said stator (1) and said movable element (3) and including:

a core (9) formed by lamination of a plurality of electromagnetic steel plates (10), and having a yoke (13) extending linearly in a direction orthogonal to a laminating direction in which said electromagnetic steel plates (10) are laminated, and a plurality of pole teeth (15) protruding from said yoke (13) toward said magnetic pole row side and having magnetic pole surfaces (19a) opposed to said magnetic pole row (7) at ends thereof,

and

multi-phase exciting windings (11) for exciting said plurality of the pole teeth (15), wherein each of said magnetic pole surfaces (19a) of two pole teeth located at both ends of a pole tooth row (16) constituted by said plurality of the pole teeth (15)

comprises a curved surface (19b) curved in such a manner that a gap between said magnetic pole row (7) and said curved surface (19b) increases with increasing distance from other pole teeth (15) adjacent thereto;

a contour of said curved surface (19b) as seen from one side of said laminating direction of said electromagnetic steel plates (10) has a shape of an arc; and

said curved surface (19b) has a lower end (19c) located nearer the magnetic pole row (7) and an upper end (19d) located farther from the magnetic pole row (7),

characterized in that:

a radius of said arc is so defined as to satisfy a relationship of $1 \leq R/\tau p \leq 3.5$. in which R is said radius of said arc, and τp is a pitch between centers of two adjacent magnets of said permanent magnets in said magnetic pole row (7);

said curved surface (19b) is so formed as to satisfy a relationship of $0.38 \leq Lt/R \leq 0.65$, in which Lt is a length between said lower end (19c) of said curved surface (19b), and an intersection of a virtual line (L1) passing through said lower end of said curved surface (19b) and extending in parallel to said magnetic pole row (7) and a virtual perpendicular (L2) passing through said upper end (19d) of said curved surface (19b) and orthogonally crossing said virtual line (L1); and

an angle α between a virtual line (L1) extending in parallel to said magnetic pole row (7) and a tangent line (L3) passing through said lower end of said curved surface is $0°$."

III. The following document is referred to in this decision:

A3: US 4 638 192 A

IV. In the contested decision, the opposition division held *inter alia* that the subject-matter of claim 1 of the patent was novel and involved an inventive step over the document A3 combined with the general knowledge of a person skilled in the art (Article 56 EPC).

V. In the statement setting out the grounds of appeal the appellant (opponent) submitted that claim 1 of the patent did not meet the requirement for inventive step of Article 56 EPC, its subject-matter being obvious when starting from the disclosure of document A3. The appellant argued in essence that the subject-matter of claim 1 differed from the disclosure of document A3 only in that, at each end of the core (9), the element (auxiliary pole) which comprised the curved, arc-shaped surface (19b) was "formed by lamination of a plurality of electromagnetic steel plates (10)".

The appellant argued that this feature did not solve the problem of reducing cogging, that problem having already been solved by the geometric design of the end poles 63, 64 in figure 7 of document A3. Rather, it solved the problem of reducing the eddy-current losses which occur in operation.

The appellant argued that starting from the motor in figure 7 of document A3, this problem was solved by the fact that not only the flux guiding part 37 was made of a steel laminations, but also the U-shaped ferromagnetic part 45.

The appellant argued *inter alia* that the solution of using a stack of laminations for the auxiliary poles was obvious from document A3 itself, in particular from the disclosures in column 1, lines 58 to 63, column 3, lines 27 to 29 and figure 2 thereof.

The appellant argued that seeking to solve the separate problems of reducing eddy current loss and cogging torque it would be obvious to make the auxiliary poles of A3, figure 7 using a stack of laminations, whilst maintaining their shape.

The fact that in A3 the angle α may be slightly above 0° was of no consequence, as according to table 3 and paragraph [0029] of the patent, cogging torque was reduced even when the angle α is as high as 10°.

VI. In the reply to the appeal the respondent (patent proprietor) submitted that the claimed subject-matter was not obvious. The respondent argued that the shape of the auxiliary poles 63, 64 in figure 7 of document A3 did not fulfil the claimed feature that:

"an angle α between a virtual line (L1) extending in parallel to said magnetic pole row (7) and a tangent line (L3) passing through said lower end of said curved surface is 0°".

According to the respondent it was not entirely clear what was meant in document A3 by the term "average wedge angle" (column 4, lines 26 to 30), i.e. it was not clear whether this might mean an average across various products, or an average of the angles at various locations within a product. The respondent submitted that the appellant was attempting to forcibly associate this feature with the feature that the angle α is 0° by a broad interpretation of this unclear term.

Furthermore, the respondent submitted that the arrangements in figure 2 and figure 7 of document A3 were alternative embodiments and that when taking teachings from document A3 the person skilled in the

art would either choose the arrangement of figure 2, to solve the problem of cogging torque, or would choose the arrangement of figure 7, to solve the problem of eddy currents. According to the respondent the skilled person would not combine these arrangements. Furthermore, even if the skilled person were to form the U-shaped ferromagnetic part 45 and the flux-conducting part 37 in Figure 7 of document A3 using laminated electromagnetic steel plates as shown in figure 2, as suggested by the appellant, this would not lead to the claimed arrangement. The upper parts of the curved surfaces would be hollow, and would thus not be filled with ferromagnetic material as they are in the end pole teeth of the patent. Thus magnetic flux would not flow as efficiently, and adverse effects due to eddy currents would not be alleviated.

The respondent submitted furthermore, that the term "bend radius" was recited in document A3, but not the term "a circular arc". It could not be inferred from the reference to "radius" in A3 that the arc was a circular arc.

VII. The Board set out their preliminary observations on the appeal in a communication of the Board of Appeal pursuant to Rule 100(2) EPC. In their preliminary observations the Board tended to concur with the appellant that seeking to achieve a reduction in eddy current losses, it would be obvious for the skilled person to adapt the embodiment of figures 7 and 8 of A3 to laminate the auxiliary poles, given that possible ways of laminating auxiliary poles were already disclosed in the embodiment of figure 1 and the embodiment of figures 2 and 3, namely by forming the auxiliary poles as part of the laminated core. Thus, it seemed that the subject-matter of claim 1 of the

contested patent was obvious in view of the disclosure of document A3 and that the requirement of Article 56 EPC was not met.

VIII. The appellant replied to the Rule 100(2) EPC communication within the specified period with a letter dated 9 November 2020. The appellant submitted that nowhere in the patent in suit was there an explicit statement that the arc of the curved surface was circular. There was merely mention of a radius, as there was in document A3.

IX. The respondent replied to the Rule 100(2) EPC communication within the specified period with a letter dated 22 February 2021. The respondent submitted that in figures 7 and 8 of document A3 the auxiliary pole 64 was shaped such that its width became narrower towards the distal end. The respondent submitted that to make such a "wedge-shape" with a stack of laminations, each lamination would have to be of a different shape. This would require a plurality of different moulds *[punching dies]*, which would make the manufacturing process meaninglessly complicated and expensive. Thus it would not be obvious to form the auxiliary pole 64 of figures 7 and 8 using a stack of laminations.

Furthermore, the respondent filed a set of claims according to an auxiliary request, citing figure 1 as a basis for the amendments made to claim 1 thereof.

The respondent explained that claim 1 of the **auxiliary request** differed from that of the patent in essence in that it comprised the additional feature that:

"a coupling portion (21) formed by the plurality of electromagnetic steel plates (10) is present between the yoke of the core and the curved surface (19b)".

The respondent argued that the amendments overcame the objection of lack of inventive step because in figure 7 of document A3 a hollow space existed above the auxiliary pole 64.

X. In a letter dated 15 March 2021 the appellant responded to the respondent's latest submissions. The appellant referred to column 1, lines 64 to 67 of A3, arguing that the narrowing of the auxiliary pole was not necessary and that A3 presented this wedge-shape as merely being advantageous compared to the "rectangular" shape shown in figure 3.

The appellant argued further, that the lack of inventive step became more apparent when starting from the arrangement of figure 1 of document A3 and working through the other figures.

Figure 1 first showed an embodiment in which the outer parts of the pole shoes of the last wound poles were extended, their faces running parallel to the direction of movement.

Figure 2 shows that it is alternatively possible to have auxiliary poles with short pole shoes outside the last wound poles of the linear motor. Here too, the faces of the pole shoes ran parallel to the direction of movement. As was shown in Figure 3, they did not taper in the direction of movement.

Figure 4 showed that it is alternatively possible to replace the auxiliary poles, including their pole shoes, by a bent sheet metal part. This sheet metal part could be tapered ("wedge-shaped") in the direction

of movement, as shown in figure 5 and as explained in column 4, lines 8 to 10.

In document A3, no advantage was given for tapering the pole shoes in the direction of movement. The skilled person would therefore not attach any significance to the tapering in the direction of movement, but would also consider, if necessary, using pole shoes that do not taper in the direction of movement, as in figures 2 and 3, for which it was explicitly disclosed in column 1, lines 64 to 66 that the auxiliary poles can be rectangular.

Figure 6 then showed that the face of the pole shoe can be bent upwards. In a variation figures 7 and 8 showed that instead of the sharp bend, there can be a gradual bend.

As a result, the person skilled in the art was given a set of tools from which they could choose as required. In particular, the person skilled in the art would choose to taper, or not to taper the auxiliary pole in the direction of movement. The person skilled in the art therefore had no problem making a linear motor with a stack of laminations as shown in figure 2 of documents A3 with the pole shoes shaped as shown in Figure 7.

Furthermore, the appellant addressed the auxiliary request, arguing that the amendment did not overcome the inventive step objection. According to the appellant, there had to be a coupling portion between the yoke of the core and the curved surface. Furthermore, the feature that the coupling portion was formed by the plurality of electromagnetic steel plates

did not add anything that was not already specified in claim 1 by the features:

- that the core was formed by lamination of a plurality of electromagnetic steel plates (10),
- that the core had a yoke and pole teeth, and
- that the pole teeth located at both ends had a curved surface, shaped in the manner set out.

XI. Oral proceedings before the Board were held on 10 February 2022.

The appellant (opponent) requested that the decision under appeal be set aside and that the European patent be revoked.

The respondent (patent proprietor) requested that the appeal be dismissed or as an auxiliary measure that the decision be set aside and the patent be maintained in amended form on the basis of the auxiliary request filed with letter dated 22 February 2021.

The appellant maintained the objections to the main and auxiliary request for lack of inventive step over document A3. The appellant argued that even though figures 5 to 8 of A3 showed wedge-shaped auxiliary poles, it was stated in column 1 of A3 that "When viewed along an axis perpendicular to the motion plane of the armature, the auxiliary poles can be rectangular". The appellant argued that the person skilled in the art would have no difficulty manufacturing rectangular auxiliary poles from a stack of laminations in the manner shown in figures 2 and 3 of A3, and that it would be obvious to do so to reduce eddy currents in the auxiliary poles. Furthermore, it would be obvious to provide the auxiliary pole faces with the curved shape shown in figure 7 of A3 to reduce

cogging. Regarding the auxiliary request the appellant referred to the submissions in their latest letter.

The respondent argued that in figures 1 and 2 of document A3 the auxiliary pole faces were flat, not curved. Figures 4 to 8 introduced a ferromagnetic plate 45 with ends bent at an angle to form auxiliary poles to reduce cogging. However the bent ends were wedge-shaped, as set out in the last full sentence of column 1, and it would be difficult to form this shape with a laminated stack for the reasons set out in their latest letter. The bent plate 45 of A3 did not reduce eddy currents. Paragraphs [0002] and [0003] of the patent set out the disadvantages of the bent plate in A3, that it was difficult to form the optimum arc shape for reducing the cogging force, eddy current loss increased and the curved surfaces tended to deform due to external force. Regarding the auxiliary request the respondent argued that with the coupling portion between the yoke and the auxiliary pole face formed by a stack of laminations as claimed there was a further reduction in eddy currents due to the extra thickness as set out in the patent in paragraph [0022] from line 36.

Reasons for the Decision

1. *Main request, inventive step compared to document A3*

1.1 The invention as set out in document A3 relates to linear DC motors having the same basic structure as in the contested patent, i.e. having a moving part and a stationary part, which face one another across an air gap, one comprising a row of alternating permanent magnets, the other comprising a wound stator core. That is not disputed.

1.2 Document A3 points out that with such linear motors "relatively strong reluctance forces are created which impede armature movement" and seeks to eliminate these reluctance forces (column 1, lines 45 to 52). It is implicit for the skilled person that in such a motor reluctance force is synonymous with cogging force, the term used in the contested patent. That is not disputed.

1.3 As in the contested patent, document A3 eliminates reluctance/cogging forces by "attaching ferromagnetic auxiliary poles at the end pole sides which are located in the direction of motion" (column 1, lines 53 to 57).

1.4 In the paragraph from column 1, line 58 to column 2, line 15, document A3 discusses various ways in which the auxiliary poles can be formed. There it is stated that they "can be formed by lengthening the outer part of the end pole shoes" (i.e. the wound poles), however "auxiliary poles separate from the winding poles are also possible". Document A3 states that in the latter

case "it is advantageous to form the auxiliary poles with the ends of a U-shaped ferromagnetic part, said ends being bent outward, preferably at a right angle". Furthermore it is stated that when "viewed along an axis perpendicular to the motion plane of the armature, the auxiliary poles can be rectangular", however "auxiliary poles which are wedge-shaped in the direction of motion proved to be particularly useful". Document A3 furthermore states that in a preferred further embodiment of the invention "the air gap between the auxiliary poles and the pole area of the permanent magnet arrangement is also wedge-shaped". Various preferred dimensional relationships are discussed, before it is disclosed that the "auxiliary poles can be curved in the direction of motion with a curvature radius which should be 0.2 to 3 times the intercoil pitch" (emphasis added). Furthermore it is stated that "the average wedge angle formed between the auxiliary poles and the pole area of the permanent magnet arrangement should preferably be between 20° and 50°".

1.5 Document A3 goes on to describe several examples of preferred embodiments, in each of which three windings are wound around three winding poles 13, 13', 13'' of a slotted flux-conducting part (i.e. core) 14 that can be, for instance, a sheet metal stack or a sintered compact (column 3, lines 23 to 29). It is not stated why a sheet metal stack or a sintered compact are proposed, but it would be implicit for the person skilled in the art of electrical machines that such core arrangements are used to reduce eddy current losses. That is not disputed.

1.6 Document A3 discloses the following embodiments by way of examples:

- Figure 1, in which the auxiliary poles are formed by lengthening the outer part of the pole shoes 23', 23'' of the end wound poles 13', 13'';
- Figures 2 and 3, in which separate unwound auxiliary poles 34 are formed as part of the core 36, the auxiliary pole faces being rectangular and parallel to the faces of the opposed permanent magnets 27;
- Figures 4 and 5, in which separate unwound auxiliary poles 57, 58 are formed by bending the ends of a U-shaped ferromagnetic part 45 which extends over the core 37 at right angles such that wedge-shaped auxiliary pole faces are formed parallel to the faces of the opposed permanent magnets 27;
- Figure 6, which is identical to the embodiment of figures 4 and 5 except that the auxiliary poles 59, 60 are not parallel to the faces of the opposed permanent magnets 27, but at an angle thereto such that the air gap is wedge-shaped;
- Figures 7 and 8, which again is identical to the embodiment of figures 4 and 5 except that the ends of the U-shaped ferromagnetic part 45 are "bent at a bend radius R in order to form auxiliary poles 63, 64".

1.7 The Board concurs with the respondent in so far as that document A3 does not directly and unambiguously disclose a laminated core that at each end comprises an auxiliary pole, formed as part of the laminated core, having a pole face which is curved in such a manner that the gap between it and the magnetic pole row increases with increasing distance from other pole teeth of the core. Whilst A3 discloses auxiliary poles

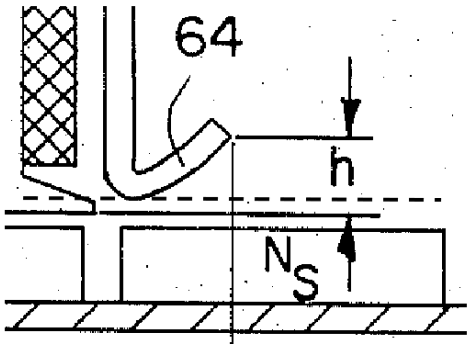
that are formed as part of the laminated core but have flat, parallel pole faces, and also discloses auxiliary poles that have a pole faces which are curved in the manner claimed, it does not directly and unambiguously disclose the combination of auxiliary poles that are both curved and part of the laminated core.

1.8 The Board nevertheless finds the appellant's argument persuasive, that starting from the embodiment of figures 7 and 8 of document A3, which has such curved pole faces, the novel aspect of forming the auxiliary poles as part of the laminated core would have the technical effect of reducing eddy current losses. Furthermore, the Board concurs with the appellant that seeking to achieve a reduction in eddy current losses, it would be obvious for the skilled person to adapt the embodiment of figures 7 and 8 by forming the auxiliary poles from the stack of laminations. The hint to do so would come from the fact that an arrangement with laminated auxiliary poles is already disclosed in the embodiment of figures 2 and 3. Given that the curved shape of the auxiliary pole face in the embodiment of figures 7 and 8 is described as being advantageous (see column 4, line 26), the Board considers that it would be obvious to retain that shape.

1.9 The Board finds the respondent's argument persuasive, that it would be problematic to form the wedge-shape shown in figure 8 (angle ß) using a stack of laminations. As the respondent has pointed out, this would require a plurality of different punching dies, which would make the manufacturing process overly complicated. However the Board considers that the skilled person would recognise this difficulty and readily adopt a rectangular shape instead. The hint to do so would come from the fact that laminated auxiliary

poles with a rectangular shape are already disclosed in the embodiment of figures 2 and 3. Shaping the faces of laminated poles in this way would not present the skilled person with any difficulties. It would be a simple matter of using a single punching die with the required shape.

1.10 Regarding the respondent's argument that in figure 7 of document A3 the shape of the auxiliary poles 63, 64 is not such that the angle α is 0°, the Board finds that with the angle α defined as it is, A3 does disclose this feature. The angle α is defined as being "an angle α between a virtual line (L1) extending in parallel to said magnetic pole row (7) and a tangent line (L3) passing through said lower end of said curved surface". In figure 7 the tangent passing through the lowest point on the curved face of the auxiliary pole 63, 64 (i.e. the point nearest the opposed magnetic pole row) must by definition be parallel to the magnetic pole row, and thus must satisfy the condition α = 0° (see the excerpt from figure 7 below, with a dashed tangent line added at the lowest point).



1.11 As to the respondent's argument that document A3 does not disclose "a circular arc", the Board notes that claim 1 of the patent does not specify that the arc-shape of the curved surface is a circular arc.

1.12 Considering the respondent's argument that if the skilled person were to form the auxiliary pole of A3, figure 7 using stacked laminations the upper part of the curved surfaces would be hollow, and thus not be filled with ferromagnetic material as they are in the end pole teeth of the patent, the Board notes that claim 1 of the patent does not specify anything regarding the upper part of the curved surfaces.

1.13 For the reasons set out above, the Board came to the conclusion that the subject-matter of claim 1 of the contested patent is obvious in view of the disclosure of document A3 and thus the requirement of Article 56 EPC is not met.

1.14 In view of the above findings the appellant's alternative line of argumentation starting from the embodiment of figures 2 and 3 of document A3 need not be addressed in this decision.

2. *Auxiliary request, inventive step compared to document A3*

2.1 Claim 1 of the auxiliary request specifies the additional feature that:

"a coupling portion (21) formed by the plurality of electromagnetic steel plates (10) is present between the yoke of the core and the curved surface (19b)"

2.2 Claim 1 of the patent as granted already specifies:

- that the core (9) is formed by lamination of a plurality of electromagnetic steel plates (10),
- that the core (9) has a yoke (13) and a plurality of pole teeth (15), and

- that the magnetic pole surfaces (19a) of each of the two pole teeth (15) located at both ends of the pole tooth row (16) have a curved surface (19b).

It is evident from this combination of features in claim 1 of the patent that each end pole tooth is formed by the plurality of electromagnetic steel plates, that it is present between the yoke and the curved surface (19b) of its magnetic pole surface (19a), and that it couples the yoke and the curved surface (19b) together (being formed by the same steel plates).

2.3 For these reasons, the Board concurs with the appellant that the amendments according to claim 1 of the auxiliary request do not add any technical features to the claimed subject-matter and therefore cannot overcome the objection of lack of inventive step.

2.4 Hence, the Board came to the conclusion that the subject-matter of claim 1 of the auxiliary request is obvious in view of the disclosure of document A3 and thus the requirement of Article 56 EPC is not met.

3. *Conclusion*

As none of the respondent's requests meet the requirements of the convention, the Board acceded to the appellant's request to revoke the patent.

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:

U. Bultmann R. Lord

Decision electronically authenticated