United States Patent	12391373
Kind Code	B2
Date of Patent	August 19, 2025
Inventor(s)	Fernandez; Maxime et al.

Speed reducer for a device for driving a wheel of an aircraft landing gear

Abstract

A mechanical speed reducer, in particular for a device for driving at least one wheel of an aircraft landing gear, this reducer including a first sun gear including external toothing, first planet gears meshed with the external toothing of the first sun gear, these first planet gears being carried by a first planet carrier, a stationary ring gear meshed with the planet gears, and second planet gears meshed with a ring gear and with an external toothing of said first planet carrier, these second planet gears being carried by a second planet carrier.

Inventors: **Fernandez; Maxime (Moissy-Cramayel, FR), Francois; Loic (Moissy-Cramayel, FR), Morelli; Boris Pierre Marcel (Moissy-Cramayel, FR), Peltier; Jordane Emile Andre (Moissy-Cramayel, FR)**

Applicant: **SAFRAN TRANSMISSION SYSTEMS** (Colombes, FR)

Family ID: **1000008768196**

Assignee: **SAFRAN TRANSMISSION SYSTEMS (Colombes, FR)**

Appl. No.: **18/466330**

Filed: **September 13, 2023**

Prior Publication Data

Document Identifier	Publication Date
US 20240092479 A1	Mar. 21, 2024

Foreign Application Priority Data

FR	FR2209339	Sep. 16, 2022

Publication Classification

Int. Cl.: **B60K17/04** (20060101); **B60B27/00** (20060101); **B60K7/00** (20060101); **B64C25/32** (20060101); **F16H1/46** (20060101); **F16H3/66** (20060101)

U.S. Cl.:

CPC **B64C25/405** (20130101); **B60B27/0015** (20130101); **B60B27/0047** (20130101); **B60K7/0007** (20130101); **F16H1/46** (20130101); B60K17/046 (20130101); F16H3/663 (20130101); F16H2200/202 (20130101); F16H2200/2097 (20130101)

Field of Classification Search

CPC: F16H (1/46); F16H (3/663); F16H (2200/202); F16H (2200/2097); B64C (25/405); B60K (7/0007); B60K (17/046)

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Primary Examiner: Dang; Tinh

Attorney, Agent or Firm: WOMBLE BOND DICKINSON (US) LLP

Background/Summary

TECHNICAL FIELD OF THE INVENTION

(1) This invention relates to a mechanical speed reducer and to a device for driving at least one wheel of an aircraft landing gear comprising such a reducer.

TECHNICAL BACKGROUND

(2) The technical background comprises in particular the documents FR-A1-3 022 858, US-A1-2019/191575 and US-A1-3,711,043.

(3) An aircraft comprises landing gears equipped with wheels for moving the aircraft on the ground over a tarmac. This taxiing can be achieved by propelling the aircraft using its turbomachines.

(4) To limit the fuel consumption and the environmental impact, it is known to carry out this taxiing electrically. The electric taxiing is achieved by driving the wheels of a landing gear by an electric motor.

(5) The present application proposes an improvement on existing technologies and thus relates to an electric motor device for driving at least one wheel of an aircraft landing gear.

(6) A solution consisting of using a mechanical reducer to transmit the power of an electric motor to a wheel of a landing gear was proposed by the Applicant in the document EP-A1-3 882 136.

(7) The role of a mechanical reducer is to modify the speed and torque ratio between the input axle and the output axle of a mechanical system.

(8) In the remote field of the aircraft turbomachines, a mechanical reducer is used to transmit power between two rotating mechanical shafts.

(9) There are many different types of reducers, for example differential, planetary, epicyclic, with intermediate lines, with reduction stages in series, etc.

(10) In the prior art of the dual-flow turbomachines, the reducers are of the planetary or epicyclic type. Such a reducer comprises a central pinion, referred to as sun gear, a ring gear and pinions referred to as planet gears, which are engaged between the sun gear and the ring gear. The planet gears are maintained by a frame referred to as planet carrier. The sun gear, the ring gear and the planet carrier are planetary because their axes of revolution coincide with the longitudinal axis of the turbomachine. The planet gears each have a different axis of revolution equally distributed on the same operating diameter around the axis of the planetaries. These axes are parallel to the longitudinal axis of the turbomachine.

(11) There are several reducer architectures. In other similar applications, there are architectures referred to as differential or “compound”. In a planetary reducer, the planet carrier is stationary and the ring gear is the output shaft of the device which rotates in the opposite orientation of the sun gear. In an epicyclic reducer, the ring gear is stationary and the planet carrier is the output shaft of the device which rotates in the same orientation as the sun gear. On a compound reducer, no element is attached in rotation. The ring gear rotates in the opposite orientation of the sun gear and the planet carrier.

(12) The reducers can consist of one or more meshing stages. This meshing is ensured in different ways such as by contact, friction or magnetic field.

(13) In the present application, “stage” or “toothing” means at least one series of meshing teeth with at least one series of complementary teeth. A toothing can be internal or external.

(14) A planet gear may comprise one or two meshing stages. A single-stage planet gear comprises a toothing that can be straight, helical or herringbone, and whose teeth are located on a same diameter. This toothing cooperates with both the sun gear and the ring gear.

(15) A double-stage planet gear comprises two toothings that are located on different diameters. A first toothing cooperates with the sun gear and a second toothing generally cooperates with the ring gear.

(16) A reducer with a meshing double stage has the advantage of having a higher reduction ratio than a reducer with a single meshing stage of the same overall dimensions.

(17) In the context of a device for driving at least one wheel of a landing gear, the use of an electric motor and a reducer to drive the wheel generates considerable overall dimensions constraints. The outer diameter of the reducer is limited by the size of the rim of the wheel, and the inner diameter of the reducer is strongly constrained by the diameter of the hub of the wheel. In addition, the use of an electric motor generally rotating at high speeds requires the use of a reducer with a high

reduction ratio in order to offer an output speed that corresponds to the low speed of rotation of the wheel. The current epicyclic and planetary gear trains do not offer these levels of reduction in such a small space.
(18) The invention proposes a solution to at least part of these problems, which is simple, effective and economical.

SUMMARY OF THE INVENTION

(19) The invention relates to a mechanical speed reducer, in particular for a device for driving at least one wheel of an aircraft landing gear, this reducer comprising: a first sun gear movable in rotation about an axis X and comprising an external toothing, first planet gears distributed around the axis X and meshed with the external toothing of the first sun gear, these first planet gears being movable in rotation around axes Y parallel to the axis X and being carried by a first planet carrier movable in rotation around the axis X, a stationary ring gear meshed with the planet gears, characterised in that it further comprises: second planet gears distributed around the axis X and meshed with a ring gear and with an external toothing of said first planet carrier, these second planet gears being movable in rotation around axes Z parallel to the axis X and being carried by a second planet carrier movable in rotation around the axis X.
(20) The invention proposes a double gear train epicyclic reducer. A first epicyclic gear train is formed by the first sun gear, the first planet gears carried by the first planet carrier and the ring gear. A second epicyclic gear train is formed by the first planet carrier, which forms a second sun gear, the second planet gears carried by the second planet carrier, and the ring gear. We can therefore see that there is one element in common to the two epicyclic gear trains, and that is the first planet carrier for the first gear train and the second sun gear for the second gear train. In practice, this can mean equipping the first planet carrier with an external pinion toothing which are centred on the axis X and which can mesh with the toothings of the second planet gears. The ring gears of the first and second gear trains can be the same or different.
(21) The reducer thus comprises the first sun gear, which forms the input of the reducer, and the second planet carrier, which forms the output of the reducer. The ring gear or ring gears are stationary.
(22) The planet gears are advantageously of the double-stage type and thus comprise independent toothings for meshing with the sun gear and the ring gear. In this case, the reducer is of the double-stage and double epicyclic gear train type.
(23) The reducer according to the invention has a high reduction ratio compared with the reducers of the prior art, thanks to its double epicyclic gear train.
(24) The invention is compatible with a multi-stage reducer as described above. It is also compatible with a reducer where the planet carrier is movable in rotation, such as the epicyclic or differential reducers. It is also compatible with any type of toothings (straight, helical, herringbone, etc.). The invention is further compatible with a planet carrier of the monobloc type or of the cage and cage carrier type. These different types of reducer are well known to those persons skilled in the art. The solution proposed below is compatible with any type of planet gear bearing, whether it consists of rolling elements, a hydrodynamic bearing, etc.
(25) The reducer according to the invention may comprise one or more of the following characteristics, taken alone or in combination with each other: the first planet gears each comprise a first external toothing meshed with the external toothing of the first sun gear, and a second external toothing meshed with a first internal toothing of a first ring gear; the first and second toothings of each of the first planet gears have different diameters and/or different numbers of teeth; the second planet gears each comprise a first external toothing meshed with the external toothing of the first planet carrier; the second planet gears each comprise a second external toothing meshed with a second internal toothing of said first ring gear; the first and second toothings of each of the second planet gears have different diameters and/or different numbers of teeth; the axes Y are located on a first circumference and the axes Z are located on a second circumference, the first and second

circumferences having different diameters; the axes Y are located on a first circumference and the axes Z are located on a second circumference, the first and second circumferences having identical diameters; the number of first planet gears is equal to the number of second planet gears; the number of first planet gears is different from the number of second planet gears; the toothings of the first and second planet gears are herringbone-shaped and the toothings of the ring gear or ring gears are helical; the first and second planet gears are guided in rotation by bearings located at the longitudinal ends of the planet gears or radially inside the toothings of these planet gears.
(26) The present invention also relates to a device for driving at least one wheel of an aircraft landing gear, this device comprising: at least one landing gear wheel, this wheel comprising a rim with an axis of rotation, an electric motor comprising a shaft, a mechanical transmission system between the shaft of the motor and the rim, this mechanical transmission system comprising a mechanical speed reducer as described above.

Description

BRIEF DESCRIPTION OF THE FIGURES
(1) Further characteristics and advantages will be apparent from the following description of a non-limiting embodiment of the invention with reference to the appended drawings in which:
(2) FIG. **1** is a schematic perspective view of a wheel of an aircraft landing gear and a device for driving this wheel,
(3) FIG. **2** is a partial axial sectional view of a mechanical reducer,
(4) FIG. **3** is another partial axial sectional view of a mechanical reducer,
(5) FIG. **4** is a schematic axial sectional view of a reducer according to one embodiment of the invention,
(6) FIG. **5** is a schematic axial sectional view of a device for driving a wheel of an aircraft landing gear, this device comprising the reducer of FIG. **4**;
(7) FIG. **6** is a schematic view in axial cross-section of a device for driving a wheel of an aircraft landing gear, this device comprising a reducer according to a variant embodiment of the invention,
(8) FIGS. **7***a* and **7***b* are schematic views, respectively in perspective and transparency on the one hand, and in axial cross-section on the other hand, of another variant embodiment of the reducer according to the invention;
(9) FIG. **8** is a schematic axial sectional view of a planet gear and guide bearings for guiding this planet gear; and
(10) FIG. **9** is a schematic axial sectional view of a planet gear and guide bearings for guiding this planet gear.
DETAILED DESCRIPTION OF THE INVENTION
(11) FIG. **1** shows a device **10** for driving at least one wheel **12** of an aircraft landing gear **14**.
(12) The wheel **12** comprises a rim **16** with an axis of rotation X. Conventionally, this rim **16** is generally tubular or disc-shaped and carries a tyre **18** on its periphery.
(13) The device **10** comprises an electric motor **20** and a mechanical transmission system **22** between a shaft of the motor **20** and the rim **16** of the wheel **12**.
(14) In the example shown, the motor **20** and the system **22** each have a generally annular shape and are centred on the axis X. They are arranged next to each other and the system **22** is installed between the motor **20** and the rim **16**. A portion of the system **22**, or even a portion of the motor **20**, could be housed in the rim **16** to reduce the overall dimensions of the device **10**. The motor **20** and the system **22** can be protected by an outer cylindrical cover **26** projecting from one side of the rim **16** or of the tyre **18**.
(15) The mechanical transmission system **22** comprises a mechanical speed reducer **28**, examples of embodiments of which are shown in FIGS. **2** and **3**.

(16) FIG. **2** shows an epicyclic reducer **28**. At the input, the reducer **28** is connected to a shaft **30**, for example by means of internal splines **32***b*. The shaft **30** drives a planetary pinion referred to as the sun gear **32**. Typically, the sun gear **32** drives a series of pinions referred to as planet gears **34**, which are equally spaced on the same diameter around the axis X of rotation of the sun gear **32**. This diameter is equal to twice the operating centre distance between the sun gear **32** and the planet gears **34**. The number of planet gears **34** is generally defined as between three and seven.
(17) The assembly of the planet gears **34** is held by a frame referred to as planet carrier **36**. Each planet gear **34** rotates about its own axis Y and meshes with a ring gear **38**.
(18) In the output we have: In this epicyclic configuration, the assembly of the planet gears **34** drive in rotation the planet carrier **36** about the axis X. The ring gear **38** is attached to a stator via a ring gear carrier **40** and the planet carrier **36** is attached to another shaft **42**. In another planetary configuration, the assembly of the planet gears **34** is held by a planet carrier **36** which is attached to a stator. Each planet gear drives the ring gear **38** which is connected to the shaft **42** via a ring gear carrier **40**. In another differential configuration, the assembly of the planet gears **34** is held by a planet carrier **36** which is connected to the shaft **30**. Each planet gear **34** drives the ring gear **38** which is fitted to the shaft **42** via a ring gear carrier **40**.
(19) Each planet gear **34** is mounted free in rotation by means of a bearing **44**, for example of the rolling or hydrodynamic bearing type. Each bearing **44** is mounted on one of the axles **36***b* of the planet carrier **36** and all the axles **36***b* are positioned relative to each other using one or more structural frames **36***a* of the planet carrier **36**. The number of axles **36***b* and bearings **44** is equal to the number of planet gears **34**. For reasons of operation, assembly, manufacture, inspection, repair or replacement, the axles **36***b* and the frame **36***a* may be separated into several parts.
(20) For the same reasons mentioned above, the toothing **34***a* of a planet gear **34** can be separated into several helices or teeth each having a median plane P, P′. In the example shown, each planet gear **34** comprises two series of herringbone teeth cooperating with a ring gear **38** separated into two half-ring gears: An upstream annulus **38***a* consisting of a rim **38***aa* and an attachment half-flange **38***ab*. On the rim **38***aa* is the front helix meshed with a helix of the toothing **34***a* of each planet gear **34**. The helix of the toothing **34***a* also meshes with that of the sun gear **32**. A downstream annulus **38***b* consisting of a rim **38***ba* and an attachment half-flange **38***bb*. The rear helix is located on the rim **38***ba* and is meshed with a helix of the toothing **34***a* of each planet gear **34**. The helix of the toothing **34***a* also meshes with that of the sun gear **32**.
(21) If the helix widths vary between the sun gear **32**, the planet gears **34** and the ring gear **38** because of the toothing overlaps, they are all centred on a median plane P for the upstream teeth and on another median plane P′ for the downstream teeth.
(22) FIG. **2** illustrates the case of a reducer with a single meshing stage, i.e., the same toothing **34***a* of each planet gear **34** cooperates with both the sun gear **32** and the ring gear **38**. Although the toothing **34***a* comprises two sets of teeth, these teeth have the same average diameter and form a single toothing referred to as herringbone.
(23) The attachment half-flange **38***ab* of the upstream annulus **38***a* and the attachment half-flange **38***bb* of the downstream annulus **38***b* form the attachment flange **38***c* of the ring gear. The ring gear **38** is attached to the ring gear carrier **40** by assembling the attachment flange **38***c* of the ring gear **38** and an attachment flange **40***a* of the ring gear carrier **40** using a bolted assembly, for example.
(24) FIG. **3** shows another example of reducer architecture, referred to as a double meshing stage, in which each planet gear **34** comprises two separate toothings **34***a***1**, **34***a***2** configured to cooperate respectively with the ring gear **38** and the sun gear **32**.
(25) In this FIG. **3**, the elements already described in the foregoing are designated by the same references.
(26) The toothing **34***a***1** meshing with the ring gear **38** has an average diameter D**2** and is located in a median plane P. The toothing **34***a***2** meshing with the sun gear **32** has an average diameter D**1** and is located in another median plane P′. The median planes P, P′ are parallel to each other and

perpendicular to the axis X. The diameter D**2** is smaller than the diameter D**1**. Finally, each toothing **34***a***1**, **34***a***2** comprises a single helix.
(27) FIG. **4** shows a first embodiment of a mechanical speed reducer **28** according to the invention, which has the particularity of being a double epicyclic gear train.
(28) The reducer **28** comprises: a first sun gear **32** movable in rotation about an axis X and comprising external toothing **32***a*, first planet gears **34** distributed around the axis X and meshing with the external toothing **32***a* of the first sun gear **32**, these first planet gears **34** being movable in rotation around axes Y parallel to the axis X and being carried by a first planet carrier **36** movable in rotation around the axis X, and a stationary ring gear **38** meshed with the planet gears **34**.
(29) The reducer **28** also comprises: second planet gears **46** distributed around the axis X and meshed with a ring gear **38** and with an external toothing **36***a* of the first planet carrier **36**, these second planet gears **46** being movable in rotation around axes Z parallel to the axis X and being carried by a second planet carrier **48** movable in rotation around the axis X.
(30) In the example shown, the sun gear **32** comprises a shaft **32***c* which may be that of the motor **20** or which may be connected to the shaft of the motor **20**, and a pinion comprising the external toothing **32***a* at its external periphery.
(31) The reducer **28** is of the double-stage type, i.e., the first and second planet gears **34**, **46** are each of the double-stage type and comprise two independent toothings **34***a*, **34***b*, **46***a*, **46***b*.
(32) The first planet gears **34** comprise a first toothing **34***a* meshed with the toothing **32***a* of the sun gear **32**, and a second toothing **34***b* meshed with a first toothing **52** of the ring gear **38**. The first toothing **34***a* has a larger diameter and/or number of teeth than the second toothing **34***b*. The toothing **34***a* is located on the side of the shaft **32***c* and therefore of the electric motor **20**, and the toothing **34***b* is therefore located on the opposite side, i.e., on the side of the wheel **12**.
(33) The first planet carrier **36** comprises or carries physical axles **36***b* for supporting or guiding the first planet gears **34**. The first planet carrier **36** also comprises a shaft **36***c* or a segment of shaft connected to a pinion comprising the external toothing **36***a* at its external periphery.
(34) The second planet gears **46** comprise a first toothing **46***a* meshed with the toothing **36***a* of the first planet carrier **36** forming a second sun gear, and a second toothing **46***b* meshed with a second toothing **54** of the ring gear **38**. The first toothing **46***a* has a larger diameter and/or number of teeth than the second toothing **46***b*. The toothing **46***a* is located on the side of the wheel **12**, and the toothing **46***b* is therefore located on the opposite side, i.e., on the side of the motor **20**.
(35) In the example shown, the internal toothings **52**, **54** are carried by a same ring gear **38**. Alternatively, they could be carried by different ring gears. The ring gear **38** is stationary and is therefore intended to be attached to a stator of the device **10**.
(36) The second planet carrier **48** comprises or carries physical axles **48***b* for supporting or guiding the second planet gears **46**. The second planet carrier **48** also comprises a shaft **46***c* or a segment of shaft which is intended to be connected to the rim **16** of the wheel **12**.
(37) As shown in FIG. **4**, the shafts **32***c*, **36***c* and **46***c* are centred and guided in rotation about the axis X by bearings **50**.
(38) The axes Y and Z are located respectively on circumferences C**1**, C**2** of the same diameter D**3**, D**4**. Alternatively, the diameters D**3**, D**4** of these circumferences C**1**, C**2** could be different.
(39) The toothings **34***a*, **34***b*, **32***a* are of any type, for example herringbone. The toothings **46***a*, **46***b*, **36***a* are of any type and preferably herringbone-shaped. The toothings **52**, **54** are preferably helical.
(40) FIG. **5** shows a device **10** for driving a wheel **12** of an aircraft landing gear, comprising the reducer **28** shown in FIG. **4**.
(41) The motor **20** of the device **10** comprises a rotor **20***a* and a stator **20***b*. The rotor **20***a* has an annular shape and is connected to the shaft **32***c*. The stator **20***b* is annular in shape and extends around the rotor **20***a* and also on a side of the rotor **20***a* opposite the reducer **28**.
(42) The shaft **46***c* is connected to the rim **16** of the wheel **12**. This connection can be made by a disengagement system **16**′ which is able to adopt two positions: a first position in which the output

shaft of the reducer **28**, and in particular the shaft **56***c*, is coupled to the rim **16** or to the shaft of the rim, and a second position in which this output shaft is uncoupled from the rim **16**, which is then freewheeling.
(43) The stator **20***b* of the motor **20** comprises a rod **20***c* which is centred on the axis X and extends along the axis X successively through the reducer **28** and the rim **16**.
(44) FIG. **6** shows a variant embodiment of a device **10** for driving a wheel **12** of an aircraft landing gear according to the invention.
(45) The above description in relation to FIGS. **4** and **5** applies to the reducer **28** in FIG. **6**.
(46) FIG. **6** shows that the toothings **32***a* and **34***a* are located in the same plane P**1** perpendicular to the axis X. The toothings **34***b* and **52** are located in the same plane P**2** perpendicular to the axis X.
(47) The toothings **46***a* and **36***b* are located in the same plane P**3** perpendicular to the axis X. The toothings **46***b* and **54** are located in the same plane P**4** perpendicular to the axis X.
(48) The ring gear **38** is positioned between the planes P**1** and P**3**. The ring gear **38** has an external diameter D**5** which defines the external diameter of the reducer **28** and which is preferably smaller than the external diameter D**6** of the rim **16** so that portion of the reducer **28** can be axially housed in the rim **16**.
(49) FIGS. **7***a* and **7***b* show another variant embodiment of a device **10** for driving a wheel **12** of an aircraft landing gear according to the invention.
(50) The description given above in relation to FIGS. **4** to **6** applies to the reducer **28** in FIGS. **7***a* and **7***b*.
(51) It can be seen that the number of first planet gears **34**, here eight, is greater than the number of second planet gears **46**, here five.
(52) FIG. **8** shows an example of how the planet gears **34**, **46** of the reducer **28** are guided. The planet gears **34**, **46** are guided by rolling bearings **45**, which in this case are roller bearings. There are two guide bearings **45** for guiding each planet gear **34**, **46**, mounted around the longitudinal ends of this planet gear, between these ends and the planet carrier **36**, **48**. Each of the bearings **45** comprises an internal ring **45***a* carried by the planet gear **34**, **46** or integrated into it, and an external ring **45***b* carried by the planet carrier **34**, **48**. The rollers **45***c* are mounted between the rings **45***a*, **45***b*.
(53) FIG. **8** shows that the toothings **34***a*, **46***a* of the planet gears **34**, **46** are located between the bearings **45**. This arrangement allows the moments applied to the planet gears **34** by the meshing to be balanced as effectively as possible.
(54) Alternatively, as shown in FIG. **9**, the planet gears **34**, **46** are guided by needle bearings **47**. These bearings **47** are two in number and are mounted radially inside the planet gears **34**, **46**. Each of the bearings **47** is radially aligned with one of the toothings **34***a*, **46***a* of the planet gear **34**, **46**. This assembly allows to reduce the axial overall dimension.
(55) Each of the bearings **47** may have an axial length or dimension L**1**, L**2** measured along the axis Y or Z, which is at least 80% of the axial length or dimension L**3**, L**4** of the corresponding toothing **34***a*, **46***a*.
(56) In yet another variant embodiment not shown, the guide bearings **34**, **46** for guiding the planet gears are plain bearings or hydrodynamic bearings.
(57) The reducer **28** as described above offers a high reduction ratio compared with the reducers of the prior art, and has a small overall dimensions, these two parameters being important for the use of this reducer in a device for driving at least one wheel of an aircraft landing gear.

Claims

1. A mechanical speed reducer for a device for driving at least one wheel of an aircraft landing gear, this reducer comprising: a first sun gear movable in rotation about an axis X and comprising an external toothing, first planet gears distributed around the axis X and meshed with the external

toothing of the first sun gear, these first planet gears being movable in rotation around axes Y parallel to the axis X and being carried by a first planet carrier movable in rotation around the axis X, a stationary ring gear meshed with the planet gears, second planet gears distributed around the axis X and meshed with the ring gear and with an external toothing of said first planet carrier, these second planet gears being movable in rotation around axes Z parallel to the axis X and being carried by a second planet carrier movable in rotation around the axis X, wherein: the first planet gears each comprise a first external toothing meshed with the external toothing of the first sun gear, and a second external toothing meshed with a first internal toothing of the ring gear, the first and second toothings of each of the first planet gears having different diameters and/or different numbers of teeth, and the second planet gears each comprise a first external toothing meshed with the external toothing of the first planet carrier, and a second external toothing meshed with a second internal toothing of said ring gear, the first and second toothings of each of the second planet gears having different diameters and/or different numbers of teeth.

2. The reducer according to claim 1, wherein the axes Y are located on a first circumference and the axes Z are located on a second circumference, the first and second circumferences having different diameters.

3. The reducer according to claim 1, wherein the axes Y are located on a first circumference and the axes Z are located on a second circumference, the first and second circumferences having identical diameters.

4. The reducer according to claim 1, wherein the number of first planet gears is equal to the number of second planet gears.

5. The reducer according to claim 1, wherein the number of first planet gears is different from the number of second planet gears.

6. The reducer according to claim 1, wherein the toothings of the first and second planet gears are herringbone-shaped and the toothings of the ring gear are helical.

7. The reducer according to claim 1, wherein the first and second planet gears are guided in rotation by bearings which are located at the longitudinal ends of the planet gears or radially inside the toothings of these planet gears.

8. A device for driving at least one wheel of an aircraft landing gear, this device comprising: at least one landing gear wheel, this wheel comprising a rim having an axis of rotation, an electric motor comprising a shaft, a mechanical transmission system between the shaft of the motor and the rim, this mechanical transmission system comprising a mechanical speed reducer according to claim 1.