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(71) Applicant: **ORONA, S. COOP.**
20120 Hernani (Guipuzcoa) (ES)

(72) Inventors:
• **URCHEGUI IRAZOQUI, Mikel**
20120 Hernani (Guipúzcoa) (ES)
• **MARTÍN OYARZABAL, Izaro**
Hernani (Guipúzcoa) (ES)
• **ZURBITU GONZALEZ, Javier**
20500 Arrasate-Mondragon (Guipuzcoa) (ES)

(74) Representative: **Carpintero Lopez, Francisco et al**
Herrero & Asociados, S.L.
Alcalá 35
28014 Madrid (ES)

(54) **SUSPENSION AND TRACTION SYSTEM AND ELEVATOR COMPRISING AT LEAST ONE PULLEY AND A SUSPENSION AND TRACTION ELEMENT WITH AT LEAST ONE SHAPE MEMORY ALLOY WIRE**

(57) The present invention relates to a suspension and traction system provided with at least one suspension and traction element and at least one pulley, wherein pulley diameter, $\varnothing_{\text{pulley}}$, is less than or equal to 130 mm, the suspension and traction element comprises a load bearing section with at least one shape memory alloy

wire having diameter $\varnothing_{\text{smawire}}$, said shape memory alloy being chosen from shape memory alloys the characteristic A_f temperature of which is below room temperature, and the value of the quotient $\varnothing_{\text{pulley}}/\varnothing_{\text{smawire}}$ is between 50 and 2000. The fatigue lifetime is improved with this configuration.

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Description

Field of the Art

[0001] The present invention relates to suspension and traction systems with a pulley and the load bearing elements or suspension and traction elements thereof. It particularly relates to a system provided with at least one pulley and a suspension and traction element with at least one shape memory alloy (SMA) wire.

State of the Art

[0002] Suspension and traction systems, such as elevators, are provided with a car, a counterweight and one or more pulleys and they are operated by traction machines or units, usually an electric motor, connected to the traction pulley. The motor is arranged in a machine room above the shaft through which the car travels. There is currently a trend in designing and developing elevators to optimize use of the shaft and dispense with the machine room. Components such as motors are small enough to allow enormous space savings. Pulleys, however, cannot be reduced as much as desired because they have the problem that the smaller they are, the greater the wear the bearing elements sustain as the pass through said pulleys. The stresses sustained due to traction and contact drastically reduce the fatigue lifetime of ropes or belts. Patent application EP2511219 seeks to prevent wear between adjacent strands of the rope by preventing localized contacts and separating them with resin. However, the invention does not solve the problem of the increases in stresses due to the bending component when the pulley diameter is reduced.

Object of the Invention

[0003] To prevent degradation of the suspension and traction element as it passes through smaller sized pulleys, the present invention is based in recognizing that said degradation is considerably reduced when a martensite transformation takes place in bearing elements provided with at least one shape memory alloy wire. Said transformation enables an increase in flexibility with large recoverable deformations and without a large increase in stress. The present invention therefore provides a suspension and traction system provided with at least one suspension and traction element and at least one pulley wherein pulley diameter, $\varnothing_{\text{pulley}}$, is less than or equal to 130 mm, the suspension and traction element comprises a load bearing section with at least one shape memory alloy wire chosen from the shape memory alloys the characteristic A_f temperature of which is below room temperature and the value of the $\varnothing_{\text{pulley}}/\varnothing_{\text{smawire}}$ quotient is between 50 and 2000.

[0004] Characteristic A_f temperatures below room temperature assure that the invention will work.

[0005] The added value of shape memory alloys is

based on the unique property that such materials have, i.e., superelasticity. This property originates in the special characteristics of martensite transformation occurring in these materials when they are subjected to a certain level of stress. This peculiar behavior makes these materials extremely flexible, with considerable recoverable deformations of up to 8%, and without a large increase in stress, which is unattainable for any other metal alloy. This peculiarity allows small bending radii without damage (without permanent deformations) in the rope, which in turn allows pulleys having a smaller diameter. Furthermore, stresses between wires are homogenized, reducing contact pressures, which would improve local contacts and reduce the breaking of individual wires.

[0006] A superelastic deformation cycle begins with the application of a load. The material, in an initial austenitic state, elastically deforms until reaching a critical stress level ($\sigma_M s$) such that the austenitic structure becomes thermodynamically unstable and its transformation into detwinned martensite is induced. This direct conversion or transformation is macroscopically characterized by a great homogenous deformation in a very small increase in stress due to reorientation of the martensite variants in the load application direction. However, at the microscopic level, deformation is not homogenous, but rather the interface between austenite/martensite phases advances in the form of a transformation front from nucleation thereof until the entire structure is in the detwinned martensite phase ($\sigma_M f$).

[0007] As a result of the selection in the pulley diameter and wires proposed by the invention together with the use of an SMA material, martensitic transformation and therefore the superelasticity characteristics occur in the rope without needing any special activation signal, at normal use temperatures for an elevator. Degradation of the suspension and traction element with smaller sized pulleys is thereby prevented.

[0008] Other additional advantages and particular implementations are defined in the dependent claims.

Brief Description of the Drawings

[0009] For the purpose of aiding to better understand the features of the invention according to a preferred practical embodiment thereof, the following description refers to a set of drawings in which the following has been depicted with an illustrative character:

Figure 1 illustrates the evolution of longitudinal stress of a wire when it is bent around a pulley.

Figure 2 is a comparison between a conventional steel wire and a steel wire comprising an SMA material.

Figure 3 shows the operating conditions of an SMA wire as it passes through a pulley according to the dimensionless pulley diameter to wire diameter ratio.

Detailed Description of the Invention

[0010] The system of the invention is provided with at least one suspension and traction element (rope, belt...) and at least one pulley the diameter of which is less than or equal to 130 mm. The load bearing section of the element comprises at least one shape memory alloy wire. The following, among others, are included among the materials suitable for this purpose:

- o NiTi (49-57 at% Ni)
- o NiTiCu (8-20 at% Cu)
- o NiTiCr (< 1 at% Cr)
- o NiTiCo (< 4 at% Co)
- o NiAl (36-38 at% Al)
- o NiTiPd (0-40 at% Ni)
- o NiTiNb (0-40 at% Ni)
- o CuZn (38.5-51.5 at% Zn)
- o CuZn-X (X=Si, Sn, Al, Ga)
- o CuAlNi (28-29 at% Al, 3-4.5 at% Ni)
- o CuAlNi (16-18 at% Al, 9-13 at% Mn)
- o CuAlBe (0.5-8 at% Be, 22-25 at% Al)

[0011] All these materials undergo martensitic transformation at normal working temperatures for an elevator, since the characteristic temperature of these shape memory alloys (i.e., the A_f temperature at which transformation occurs) is below room temperature.

Figure 1 shows the longitudinal stress that a wire can sustain when it is bent around a pulley. Before traveling around the pulley (straight rope), the wire withstands a stress (σ_1), but said stress increases due to the sum of the bending component once the rope is on the pulley (σ_2). After leaving the pulley, it recovers its original stress (σ_1). While passing around the pulley, there is a localized increase as it enters the pulley (σ_3), and an also localized decrease as it leaves the pulley (σ_4).

Figure 2a shows a diagram of the suspension system of an elevator, whereas Figures 2b and 2c show the comparison of what happens with the rope as it passes around the pulley, in terms of stress/contact force and fatigue/wear, when the rope is conventional (steel) and when it is an SMA rope. In areas in which the rope is straight, the wires of the rope withstand similar stress regardless of if it is a steel rope or an SMA rope, Figure 2a. However, as it passes around the pulley, deformation increases, and while stress in a conventional rope shoots up due to the linear behavior of steel, in an SMA rope deformation occurs without an increase in stress, which means that contact forces are lower. This has an effect on the lifetime of the rope, Figure 2c, because the lower contact force the lower the fatigue and wear in wires.

Figure 3 shows the operating conditions of an SMA wire as it passes around a pulley according to the dimensionless pulley diameter to wire diameter ratio.

If this ratio is above 2000, transformation in the wire does not occur, so use of these alloys is not of interest for the described objective in the invention. When the ratio is below 50, damage occurs in the wire, which can give rise to a dramatic reduction in the lifetime of the rope. Therefore, the range of interest suitable for using SMA materials for being able to use pulleys having a smaller diameter without causing damage in the rope is between 50 and 2000.

[0012] The invention can be applied to both ropes and belts. In the case of a rope, the total section (bearing section plus sheath) has a shape the width/thickness ratio of which is substantially equal to 1. The sheath is preferably, though not necessarily, a polymer sheath.

Claims

1. Suspension and traction system provided with at least one suspension and traction element and at least one pulley, **characterized in that:**

- the pulley diameter, $\varnothing_{\text{pulley}}$, is less than or equal to 130 mm,
- the suspension and traction element comprises a load bearing section with at least one shape memory alloy wire having diameter $\varnothing_{\text{smawire}}$, said shape memory alloy being chosen from the shape memory alloys the characteristic A_f temperature of which is below room temperature,
- the value of the $\varnothing_{\text{pulley}}/\varnothing_{\text{smawire}}$ quotient is between 50 and 2000.

2. Suspension and traction system according to claim 1, **characterized in that** the material of the shape memory alloy is chosen from the following list:

- o NiTi (49-57 at% Ni)
- o NiTiCu (8-20 at% Cu)
- o NiTiCr (< 1 at% Cr)
- o NiTiCo (< 4 at% Co)
- o NiAl (36-38 at% Al)
- o NiTiPd (0-40 at% Ni)
- o NiTiNb (0-40 at% Ni)
- o CuZn (38.5-51.5 at% Zn)
- o CuZn-X (X=Si, Sn, Al, Ga)
- o CuAlNi (28-29 at% Al, 3-4.5 at% Ni)
- o CuAlNi (16-18 at% Al, 9-13 at% Mn)
- o CuAlBe (0.5-8 at% Be, 22-25 at% Al)

3. System according to any of the preceding claims, **characterized in that** the suspension and traction element is covered with a polymer sheath.

4. System according to any of the preceding claims, **characterized in that** the suspension and traction element is a rope the section of which has a shape

the width/thickness ratio of which is substantially equal to 1.

5. System according to any of claims 1-3, **characterized in that** the suspension element is a belt the section of which has a shape the width/thickness ratio of which is greater than 1. 5
6. System according to any of the preceding claims, **characterized in that** the pulley is a traction pulley. 10
7. System according to any of claims 1-5, **characterized in that** the pulley is a deflection pulley.
8. Elevator comprising a suspension and traction system according to any of the preceding claims. 15

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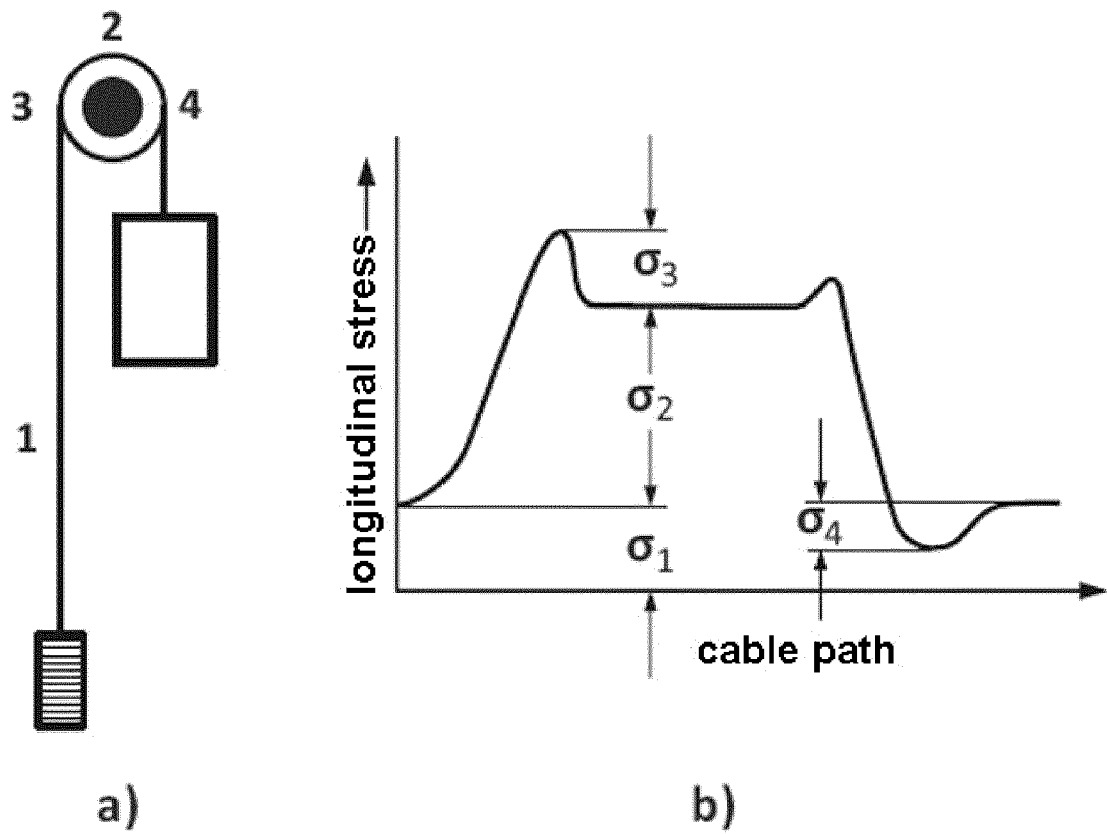


FIG. 1

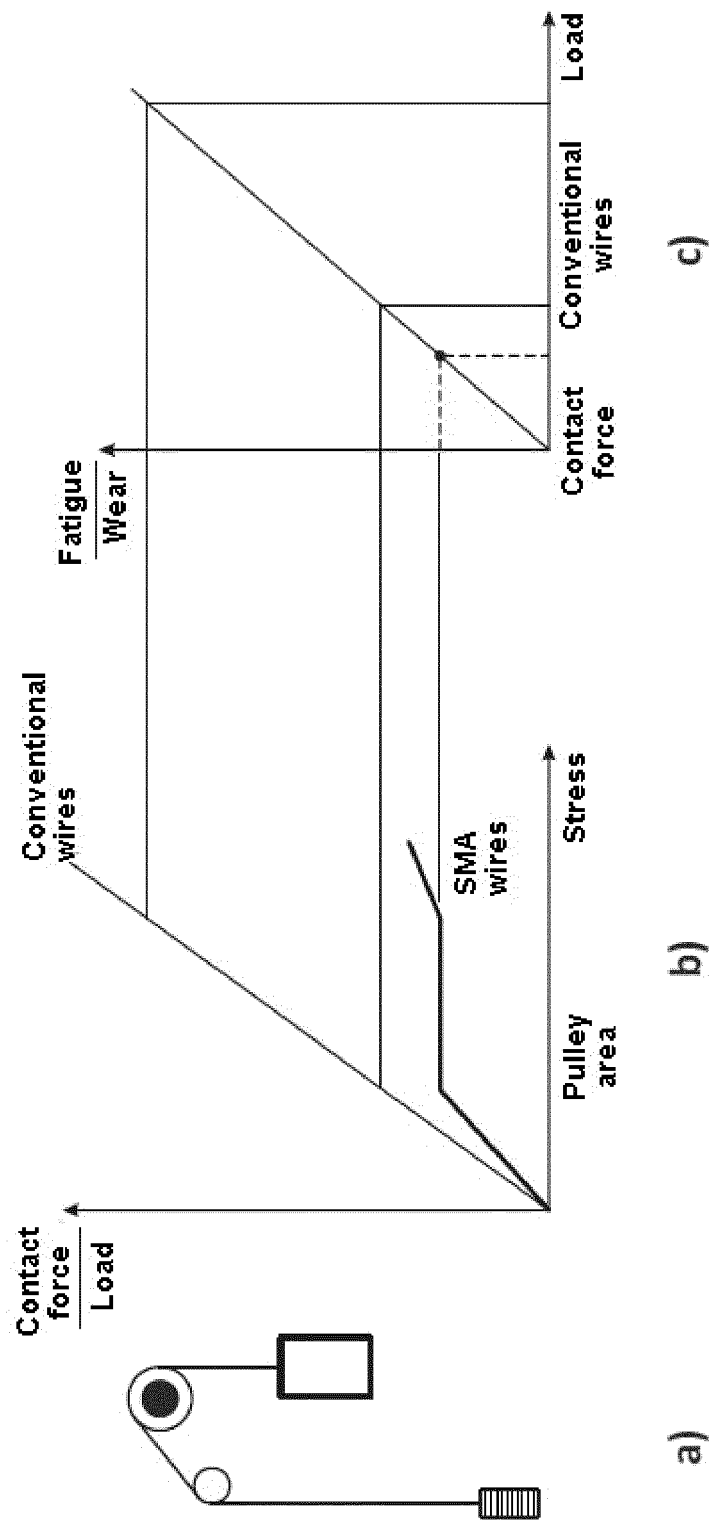


FIG. 2

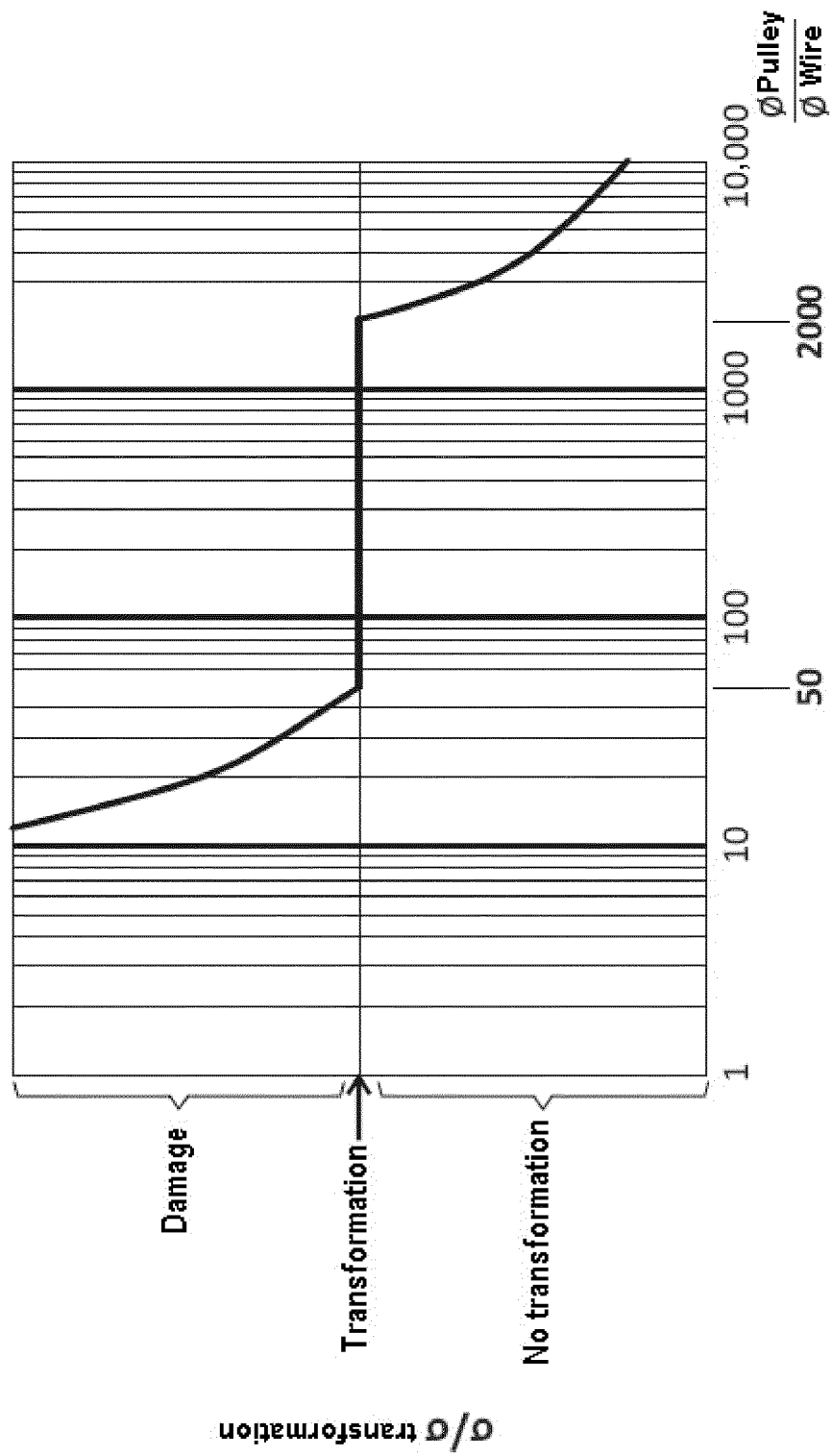


FIG. 3



EUROPEAN SEARCH REPORT

Application Number
EP 15 38 2239

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 4 018 308 A (ROGEN NEIL E) 19 April 1977 (1977-04-19) * column 1, line 30 - column 20; figure 1 *	1-8	INV. B66B7/06
A	US 2012/175025 A1 (SMITH RORY S [AE] ET AL) 12 July 2012 (2012-07-12) * paragraph [0004]; claims 1,12; figure 1 *	1-8	
			TECHNICAL FIELDS SEARCHED (IPC)
			B66B
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 31 August 2015	Examiner Janssens, Gerd
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 15 38 2239

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The members are as contained in the European Patent Office EDP file on
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31-08-2015

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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