of actuators specially designed for that purpose. It has been found that these high performance actuators are difficult to implement, particularly within compact volumes and large force/torque and power outputs. These actuators include, in particular but not exclusively, impedance controllable direct drive actuators [[2][3]]; series dynamic actuators [4]; variable stiffness actuators [5]; variable damper actuators [6]; and parallel coupled micro-macro actuators [[7][8]].

[0016] Regarding specifically rotational actuators, none of the above implementations is adapted for compact product integration and mass production.

SUMMARY

[0017] According to the present invention, there is provided a mechanical differential actuator for interacting with a mechanical load, and a corresponding method.

[0018] More specifically, in accordance with the present invention, there is provided a mechanical differential actuator for interacting with a mechanical load comprising: a first transducer; a second transducer; and a mechanical differential having three interaction ports, including a first interaction port coupled to the first transducer, a second interaction port coupled to the second transducer, and a third interaction port coupled to the load.

[0019] According to a second aspect of the present invention, there is provided a method of actuating a mechanical load comprising: providing a mechanical differential having three interaction ports; providing a first transducer; providing a second transducer; coupling the first transducer to a first interaction port of the mechanical differential; coupling the second transducer to a second interaction port of the mechanical differential; and coupling the load to a third interaction port of the mechanical differential.

[0020] The foregoing and other objects, advantages and features of the present invention will become more apparent upon reading of the following non-restrictive description of illustrative embodiments thereof, given by way of example only, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] In the appended drawings:

[0022] FIGS. **1***a*, **1***b*, **1***c*, **1***d* and **1***e* are symbols used in mechanical impedance diagrams, more specifically, respectively an ideal source of force, an ideal source of speed, a mass, a viscous damper and a spring;

[0023] FIG. **2** is an impedance diagram representing an ideal mechanical speed reducer, which is used in other mechanical impedance diagrams;

[0024] FIG. **3** is an impedance diagram representing an ideal mechanical differential having 3 ports and comprising 2 ideal mechanical speed reducers;

[0025] FIG. **4** is an impedance diagram representing a direct drive actuator;

[0026] FIG. **5** is an impedance diagram representing an ideal <<Series Elastic Actuator>> using a mechanical spring in series with an ideal source of speed;

[0027] FIG. **6** is an impedance diagram representing a hydraulic actuator;

[0028] FIG. **7** is an impedance diagram representing the implementation of a real source of speed;

[0029] FIG. **8** is an impedance diagram representing a differential actuator according to an illustrative embodiment of the present invention;

[0030] FIG. **9** is an impedance diagram representing a differential actuator with constant impedance dynamic reaction according to an illustrative embodiment of the present invention;

[0031] FIG. **10** is an impedance diagram representing a force controllable differential actuator according to an illustrative embodiment of the present invention;

[0032] FIG. **11** is an impedance diagram representing a differential actuator according to an illustrative embodiment of the present invention, with variable and controllable impedance dynamic reaction;

[0033] FIG. **12** is an impedance diagram representing a force controllable differential actuator according to an illustrative embodiment of the present invention, with variable and controllable impedance dynamic reaction;

[0034] FIG. **13** is an impedance diagram representing a representation of a serial actuator according to an illustrative embodiment of the present invention;

[0035] FIG. **14** is schematic diagram of a bar mechanism used in a speed reducer configuration mode;

[0036] FIG. **15** is a schematic diagram of a bar mechanism used in a differential configuration mode;

[0037] FIG. **16** is a perspective view of the 3 building components of a harmonic drive system comprising, from left to right, a wave generator (WG), the flexible spline (FS) and the circular spline (CS);

[0038] FIG. **17***a*, **17***b* and **17***c* are schematic diagrams of 3 possible implementations of a rotational differential actuator according to an illustrative embodiment of the present invention, using a hollow shaft harmonic drive, wherein the zigzag symbol represents transducer T**1**, for example a torsion spring, a rotational damper, a limited angle torque motor, etc.;

[0039] FIG. **18** is a perspective, cross sectional (in a vertical plane) view of a rotational differential elastic actuator according to an illustrative embodiment of the present invention;

[0040] FIG. **19** is a perspective, cross sectional (in a horizontal plane) view of a rotational differential elastic actuator according to an illustrative embodiment of the present invention; and

[0041] FIG. **20** is schematic diagram of a force controllable differential actuator according to an illustrative embodiment of the present invention, with variable and controllable impedance dynamic reaction.

DETAILED DESCRIPTION

[0042] Non-restrictive illustrative embodiments of the actuator according to the present invention will now be described.

[0043] Generally speaking, the actuator according to the non-restrictive illustrative embodiments of the present