invention comprises a mechanical differential having 3 mechanical ports, an intrinsically high impedance transducer coupled to the first mechanical port and an intrinsically low impedance transducer coupled to the second mechanical port. The third mechanical port interacts with a load. The mechanical differential along with the transducers define a dynamic relationship between force/torque and speed applied to the load at the mechanical port connected to this load.

[0044] Since impedance diagrams are used to represent the non-restrictive illustrative embodiments of the actuator according to the present invention, some mechanical components of these impedance diagrams will be first described.

Impedance Diagrams

[0045] Mechanical Differential

[0046] A mechanical differential is a mechanism that provides a coupling of 3 mechanical dipoles to respectively 3 mechanical ports of the mechanical differential. Basically, any 2-port mechanism that provides force/torque amplification by a factor K can be used in a <<3-port>> differential configuration mode.

[0047] As known to those of ordinary skill in the art, the kinematical relationship between the 3 rotational/linear speeds in a mechanical differential configuration is given by the Willis equation:

$$\hat{x}_1+K\cdot\hat{x}_2=(1+K)\cdot\hat{x}_3$$

[0048] wherein:

[0049] x_i is the angular or linear position of the i^{th} mechanical dipole coupled to the i^{th} port, i=1, 2, 3;

[0050] $\hat{x}_i$ is the angular or linear velocity of the i^{th} mechanical dipole coupled to the i^{th} port, i=1, 2, 3; and

[0051] K is an amplification factor.

[0052] The kinetic relationships between the 3 forces/torques are given by the following equations:

$$\begin{cases} F_2 = K \cdot F_1 \\ F_3 = (K+1) \cdot F_1 \end{cases}$$

[0053] wherein:

[0054] F_i is the force/torque exerted on the i^{th} mechanical dipole coupled to the i^{th} port, i=1, 2, 3.

[0055] Mechanical Impedance

[0056] A mechanical impedance can be associated to any mechanism having one degree of freedom. Mechanical impedance Z is a complex quantity that determines dynamic properties of a mechanism from the interface point of view. It can be seen as a transfer function of a black box model of the following system:

$$Z(j\omega) = \frac{\text{Force}(j\omega)}{\text{Speed}(j\omega)}$$

wherein j is the square root of −1; and ω is an angular frequency.

[0057] It is to be noted that two mechanical components that are physically connected in series are represented by their equivalent force/tension impedance symbol connected in parallel in an impedance diagram. Similarly, two mechanical components that are physically connected in parallel are represented by their equivalent force/tension impedance symbol connected in series in an impedance diagram.

[0058] Mechanical Impedance Diagram

[0059] Stationary linear systems can be modeled with impedance diagrams. Electrical impedance diagrams are abundantly used to analyze electrical circuits in steady state operation. In the following description, mechanical impedance diagrams are used to describe the non-restrictive illustrative embodiments of the present invention. For example, a force/tension analogy is used to model differential actuators. In order to interpret the mechanical impedance diagrams, one should note that:

[0060] a force/torque can be associated with a tension;

[0061] a speed can be associated with a current;

[0062] an ideal source of force/torque can be associated with an ideal source of tension;

[0063] an ideal source of speed can be associated with an ideal source of current;

[0064] a mass can be associated with an inductor;

[0065] a spring can be associated with a capacitor; and

[0066] a viscous damper can be associated with a resistor.

[0067] In this respect, FIGS. **1***a*, **1***b*, **1***c*, **1***d* and **1***e* are symbols used in the mechanical impedance diagrams. More specifically, FIG. **1***a* represents an ideal source of force/torque, FIG. **1***b* represents an ideal source of speed, FIG. **1***c* represents a mass, FIG. **1***d* represents a viscous damper and FIG. **1***e* represents a spring.

[0068] Ideal Mechanical Speed Reducer

[0069] An ideal mechanical 2-port component has no internal inertia, no friction loss and is infinitely stiff. It can be associated with an ideal electric transformer. FIG. **2** shows an impedance diagram representing an ideal mechanical 2-port speed reducer.

[0070] Equations associated with an ideal speed reducer as shown in FIG. **2** are given by:

$$\begin{cases} F_2 = K \cdot F_1 \\ \dot{x}_1 = -K \cdot \dot{x}_2 \end{cases}$$

[0071] Ideal Mechanical Differential

[0072] FIG. **3** shows an ideal mechanical differential, which is a mechanical 3-port component that has no internal inertia, no friction loss and is infinitely stiff. It can be described with an equivalent mechanical impedance diagram using two ideal speed reducers as illustrated in FIG. **2**.