PATENT SPECIFICATION

Cold-Resistant Linear Actuator with Thermal Compensation System

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ABSTRACT

A cold-resistant linear actuator system incorporating an active thermal compensation mechanism for reliable operation in sub-zero environments. The system comprises a thermally isolated housing, integrated heating elements, and a smart thermal management controller that maintains optimal operating conditions for critical mechanical components while minimizing energy consumption.

FIELD OF INVENTION

[0001] The present invention relates to electromechanical actuator systems, specifically to linear actuators designed for operation in extreme cold environments between -40 C and 0 C, with particular application in autonomous mobile robots used in cold storage and freezer facilities.

BACKGROUND

[0002] Traditional linear actuators experience significant performance degradation in cold environments due to increased mechanical resistance, lubricant viscosity changes, and thermal contraction of components. Existing solutions typically rely on passive thermal management or continuous heating, resulting in either unreliable performance or excessive energy consumption.

[0003] There exists a need for an energy-efficient linear actuator capable of maintaining precise operation in extreme cold environments while managing thermal loads effectively.

SUMMARY OF INVENTION

[0004] The present invention provides a cold-resistant linear actuator system comprising:

- A thermally isolated actuator housing with multi-layer insulation

- Distributed heating elements with zonal control
- Smart thermal management system with predictive temperature regulation
- Self-compensating mechanical components that maintain clearances across temperature ranges
- Novel low-temperature lubricant delivery system

DETAILED DESCRIPTION

[0005] Referring to Figure 1, the linear actuator assembly (100) includes:

[0006] A primary actuator housing (110) constructed of cold-resistant polymer composite with embedded thermal barriers (111, 112) creating discrete temperature zones.

[0007] An array of resistive heating elements (120-124) positioned at critical points along the actuator body, controlled individually by the thermal management system (300).

[0008] Temperature sensors (130-134) providing real-time feedback for closed-loop control.

[0009] The thermal management controller (300) implements a proprietary algorithm that:

- Monitors temperature gradients across zones
- Predicts thermal loads based on operation patterns
- Optimizes heating element activation to minimize power consumption
- Maintains critical components within operational temperature ranges

CLAIMS

A cold-resistant linear actuator system comprising:

a. An insulated housing structure;

b. A plurality of independently controlled heating elements;

c. A thermal management controller executing predictive temperature control;

d. Self-compensating mechanical components maintaining operational tolerances between -40 C and +25 C.

The system of claim 1, wherein the thermal management controller implements machine learning algorithms to optimize energy consumption while maintaining operational parameters.

The system of claim 1, further comprising a low-temperature lubricant delivery system with pressure-compensated reservoirs.

DRAWINGS

[Figure descriptions and references omitted for brevity]

DECLARATION AND GRANT

The Commissioner of Patents has granted this patent to Polar Dynamics Robotics, Inc. for a term of twenty years from the filing date, subject to the payment of maintenance fees as provided by law.

ASSIGNMENT RECORD

All rights, title, and interest in this patent have been assigned to Polar Dynamics Robotics, Inc., a Delaware corporation, as recorded in the United States Patent and Trademark Office at Reel/Frame 047123/0891.

CERTIFICATION

I hereby certify that this patent document and all statements made herein of my own knowledge are true, that statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

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Date: March 15, 2021

[USPTO Seal and Registration Numbers Omitted]