PATENT SPECIFICATION

Self-Regulating Heat Distribution in Polar Actuators

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ABSTRACT

A system and method for self-regulating heat distribution in robotic actuators operating in extreme cold environments. The invention comprises a novel thermal management architecture incorporating distributed temperature sensors, microfluidic channels, and adaptive thermal elements that maintain optimal operating temperatures for actuator components in sub-zero environments. The system enables consistent performance and extended operational life of robotic actuators in temperatures ranging from -40 C to +25 C.

BACKGROUND

[0001] Autonomous mobile robots operating in cold storage and industrial freezer environments face significant challenges related to actuator performance and reliability. Traditional actuator systems experience reduced efficiency, increased power consumption, and potential failure when exposed to sustained sub-zero temperatures.

[0002] Existing solutions typically rely on external heating elements or thermal insulation, which add bulk and reduce energy efficiency while failing to provide precise temperature control at the component level.

SUMMARY OF THE INVENTION

[0003] The present invention provides a self-regulating thermal management system for robotic actuators comprising:

- Distributed micro-scale temperature sensors
- Adaptive thermal regulation elements

- Microfluidic heat distribution channels
- Smart control architecture for thermal optimization

[0004] The system maintains optimal operating temperatures for critical actuator components while minimizing energy consumption through predictive thermal management and selective heating/cooling.

DETAILED DESCRIPTION

Thermal Sensing Architecture

[0005] The invention incorporates a network of high-precision temperature sensors (101) positioned at critical points throughout the actuator assembly. These sensors provide real-time temperature data with accuracy of 0.1 C.

[0006] Sensor placement locations include:

- Motor windings
- Bearing assemblies
- Gear interfaces
- Control electronics
- External housing surfaces

Microfluidic Distribution System

[0007] A novel microfluidic network (201) circulates thermally-optimized fluid through channels integrated into the actuator housing. The fluid composition comprises:

- 65% propylene glycol
- 30% deionized water
- 5% proprietary thermal additives

[0008] Channel geometry is optimized using computational fluid dynamics to ensure uniform thermal distribution while minimizing fluid volume and pumping requirements.

Adaptive Thermal Elements

[0009] The system employs multiple thermal regulation mechanisms:

- Resistive heating elements (301)

- Thermoelectric cooling devices (302)
- Phase-change material reservoirs (303)

[0010] Element activation is controlled by the thermal management algorithm based on:

- Current temperature readings
- Predicted thermal loads
- Available power budget
- Operating mode requirements

Control Architecture

[0011] A dedicated microcontroller executes the thermal management algorithm, which:

- Processes sensor data at 100Hz
- Predicts thermal requirements using machine learning
- Optimizes energy usage across thermal elements
- Maintains temperature within 2 C of target

CLAIMS

A self-regulating thermal management system for robotic actuators comprising:

a) A distributed temperature sensing network

b) Microfluidic thermal distribution channels

c) Multiple adaptive thermal regulation elements

d) An intelligent control system for thermal optimization

The system of claim 1, wherein the microfluidic channels are integrated into the actuator housing structure.

The system of claim 1, wherein the control system employs machine learning to predict and optimize thermal requirements.

[Claims 4-20 omitted for brevity]

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.

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Patent Examining Operation

[Additional standard USPTO form contents omitted for brevity]