

GH103 飞轮储能实验系统

产品规格书

边缘磁极驱动技术开创者，飞轮储能教学科研首选平台

□ 产品概述

GH103 飞轮储能实验系统采用独创的 W→A (Wheel-to-Arm) 边缘驱动架构，突破传统轴心驱动模式，电磁力直接作用于飞轮外缘，力臂提升 4-8 倍，完美模拟大型储能飞轮的外转子电机驱动特性。适用于高校教学、科研实验及原型验证。

□ 核心技术

● 驱动方式对比

对比项	传统轴心驱动	GH103 边缘对称驱动
力学模型	$T=F \times r$	$T=Ft \times 2R$
力臂	r (轴半径, 小)	2R (飞轮直径, 大)
力臂长度	~10-20 mm	200 mm
力矩提升	基准 (1×)	4-8 倍

● 技术特点

- 独创边缘驱动：电磁力作用于飞轮外缘，力臂提升 4-8 倍
- 对称力偶布置：8 极均匀分布，形成 4 组对称力偶
- 真实模拟：完美复现大型储能飞轮外转子电机特性

□ 系统参数

● 电磁驱动系统

参数	数值	说明
工作电压	DC 12-100V	额定工作电压
单电磁铁吸力	0.5 kgf (4.9 N)	@DC12V, 25mm×20mm
每极电磁铁数	2 个	对称布置
磁极总数	8 极	均匀分布于圆周，每极间隔 45°
电磁气隙	0.8 mm	电磁铁与飞轮外缘间隙
气隙磁导系数	1.25 mm^{-1}	$\eta=1/k$

● 机械结构参数

参数	数值	说明
飞轮半径 R	100 mm	力臂基准
力偶臂 2R	200 mm	直径，力矩作用臂
电磁铁尺寸	25mm×20mm	单电磁铁外形尺寸

□ 电磁力计算

● 总切向电磁力

$$F_t = \eta \times f \times n \times \alpha$$

● 参数定义

符号	数值	物理意义	单位
η	1.25	气隙磁导系数, $\eta=1/k$	mm^{-1}
k	0.8	电磁气隙距离	mm
f	9.8	每极电磁吸力 (等效 1 kgf, 2×0.5 kgf)	N
n	8	磁极总数	个
nm	2 每极电磁铁数	每极电磁铁数	个
α	0.5	有效做功系数 ($p/2$, 仅半数磁极切向做功)	—

□ 计算实例 (@DC12V)

● 总切向电磁力计算

$$F_t = 0.81 \times 9.8 \times 8 \times 0.5 = 1.25 \times 9.8 \times 4 = 49\text{N}$$

● 输出力矩计算

$$T = F_t \times 2R = 49\text{N} \times 0.2\text{m} = 9.8\text{N} \cdot \text{m}$$

注：单个电磁铁 8 极均匀分布（每极 45°），每极 2 个电磁铁对称布置，共 16 个电磁铁形成 4 组对称力偶。

□ 八极顺序脉冲驱动

- 8 极磁极周向均匀分布，步进式加速旋转磁场
- 每转 8 步，步进角 45°，运转平稳低振动
- 频率 10-400Hz 无级调节，转速精准可控

□ 技术参数

● 机械系统

参数	规格	说明
飞轮直径	φ200 mm	高强度铝合金，动平衡 G2.5 级
砵码配重系统	5kg + 3kg + 2kg	模块化组合，惯量 0.025-0.25 $\text{kg} \cdot \text{m}^2$ 可调
磁极配置	单级 8 极	调压式电磁线圈，φ25mm
杠杆作用角	45° ($\pi/4$)	优化力矩传递效率
气隙调节	0.2-2 mm	适应不同实验需求
整机尺寸	600×600×400 mm	实验室桌面型设计
整机重量	约 380 kg	稳固防振底座

- 电气驱动

参数	规格	说明
驱动电压	DC 12-100 V	宽范围可调, 适配多种电源
脉冲频率	10-400 Hz	对应转速 1.25-3000 RPM
正脉宽	1-20 ms	能量注入时间可调
负脉宽	1 ms	固定续流/制动
峰值功率	1.5 kW	满足加速与稳态需求
输入电源	AC 100-240V	宽电压全球通用

- 运动性能

参数	规格	说明
转速范围	10-3000 RPM	覆盖低速调试到高速储能
额定转速	600 RPM	标准教学工况
最大线速度	31.4 m/s	3000 RPM 时边缘线速度
角速度	1.05-314 rad/s	宽范围动态响应
角加速度	0.02-2 rad/s ²	精密加速控制
启动时间	<5 s (0-600 RPM)	快速建立实验条件

- 测控系统

参数	规格	说明
转速检测	霍尔传感器+磁锥	8 脉冲/转, 非接触测量
波形分析	Tektronix/ TDS7404B	100MHz, 四通道实时观测
电气测量	HAMEG HM1507-3	电压/电流/频率/占空比
转速显示	4 位 LED 数码管	直观 RPM 读数
安全防护	GH19C 智能系统	超速/过流/过热/振动/位移五重保护

● 十维实验变量

序号	变量名称	符号	调节范围	实验意义
1	配重质量	m	2-10 kg	转动惯量 J 调节
2	电磁力	F	0-500 N	驱动力矩 $T=F \cdot R$
3	驱动电压	V	12-100 V	控制励磁电流
4	驱动电流	I	0-15 A	电磁力激励源
5	脉冲频率	f	10-400 Hz	转速设定
6	正脉宽	t+	1-20 ms	能量注入时长
7	角加速度	α	实测值	动态响应输出
8	磁场位移偏角	θ	$\pm 7-13.5^\circ$	最优作用角度
9	磁感应强度	B	0-1.2 T	与电流成正比
10	飞轮相位	(x,y)	$[0,2\pi]^2$	状态空间变量

□ 核心实验功能

基础物理实验

- 转动定律验证: $\tau = J\alpha$, 力矩-角加速度线性关系
- 惯量测定实验: 对比理论计算与实测值
- 能量守恒演示: 电能→动能→电能转换

电机驱动实验

- 开关磁阻电机原理: 8极顺序同相机制
- 机械特性曲线: 转速-转矩-效率三维关系
- PWM 控制技术: 脉宽调制与占空比优化

储能系统实验

- 充放电循环: 能量存储与释放效率分析
- 动态响应测试: 阶跃/斜坡/扰动响应
- 制动能量回收: 能耗制动与反接制动对比

高级研究实验

- 多变量耦合分析: 九维参数正交实验设计
- 边缘驱动优化: 气隙/角度/频率协同优化
- 模型辨识与验证: 理论数学建模与实验对比

□ 适用对象

用户类型	应用场景	价值体现
高等院校	物理/电气/能源专业实验教学	填补飞轮储能实验设备空白，理论结合实践
职业院校	新能源技术实训	掌握储能系统装调与维护技能
科研院所	飞轮储能机理与控制研究	提供可重复的精密实验平台
企业研发	电机驱动与能量管理预研	低成本验证创新方案可行性

□ 产品优势

对比项	传统实验装置	GH103
驱动方式	轴心电机驱动	边缘磁极驱动，力矩大 4-8 倍
参数调节	固定参数，实验单一	九维可调，实验设计灵活
测量手段	机械式/简易电子	霍尔传感+数字示波器，精密采集
安全防护	基础保护	GH19C 五重智能保护，安全可靠
扩展能力	封闭结构	模块化设计，支持多级扩展与真空升级

□ 标准配置

- ✓ GH103 主机（飞轮转子、8 极驱动、控制系统、防护罩）
- ✓ 配重块组（飞轮砣：5kg×1、3kg×1、2kg×1，带快速锁紧机构）
- ✓ 泰克 TDS7404B 数字示波器（100MHz，四通道）
- ✓ HAMEG HM1507-3 多功能测量仪
- ✓ 霍尔传感器套件（8 组，含磁锥）
- ✓ 电气连接线束（电源线、信号线、BNC 线）
- ✓ 操作手册（含实验指导与理论推导）
- ✓ 出厂检验证书与质保卡

□ 可选扩展

选项	功能描述	应用场景
真空腔体套件	不锈钢真空罩+真空泵，真空度≤100Pa	高速低风阻实验，风损机理研究
二级扩展模块	增加 8 极磁极，16 极配置	高分辨率步进驱动，微振动分析
数据采集系统	16 位 USB-DAQ，4 通道同步，配套软件	自动化实验记录，大数据量采集
温度监测模块	8 路 PT100 温度传感器，磁极热管理	长时间运行热特性研究，效率优化
陶瓷轴承升级	高速轴承，支持 5000 RPM 扩展	超高速储能实验，极限性能测试

□ 服务承诺

服务项目	内容
质保期	整机 1 年, 控制器及驱动器 3 年
安装调试	免费上门安装、调试、操作培训
技术支持	7×24 小时电话支持, 远程诊断, 现场服务
软件升级	控制算法持续优化, 终身免费升级
定制开发	根据特殊需求定制参数、开发专属实验方案

□ 技术规格速查表

关键指标	数值
飞轮直径	200 mm
转速范围	10-3000 RPM
驱动电压	12-100 V
峰值功率	1.5 kW
转动惯量	0.025-0.25 kg·m ²
角加速度	0.02-2 rad/s ²
整机重量	~380 kg
防护等级	IP20

□ 联系我们

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GH103 飞轮储能实验系统——让抽象的储能理论，化为直观的实验数据。
创新边缘驱动，开启储能教学新纪元。

GH103 Flywheel Energy Storage Experimental System

Product Specification

Pioneer of Edge Magnetic Pole Drive Technology, Premier Platform for Flywheel Energy Storage Teaching and Research

□ Product Overview

The GH103 Flywheel Energy Storage Experimental System adopts the original W→A (Wheel-to-Arm) edge drive architecture, breaking through the traditional shaft-center drive mode. Electromagnetic force acts directly on the outer edge of the flywheel, increasing the lever arm by 4-8 times, perfectly simulating the outer rotor motor drive characteristics of large-scale energy storage flywheels. Suitable for university teaching, scientific research experiments, and prototype verification.

□ Core Technology

● Drive Mode Comparison

Comparison Item	Traditional Shaft-Center Drive	GH103 Edge Symmetric Drive GH103
Mechanical Model	$T=F \times r$	$T=Ft \times 2R$
Lever Arm	r (shaft radius, small)	2R (flywheel diameter, large)
Lever Arm Length	~10-20 mm ~10-20 mm	200 mm 200 mm
Torque Improvement	Baseline (1×)	4-8

● Technical Features

- Original Edge Drive: Electromagnetic force acts on the outer edge of the flywheel, increasing the lever arm by 4-8 times
- Symmetric Force Couple Arrangement: 8 poles uniformly distributed, forming 4 sets of symmetric force couple
- Realistic Simulation: Perfectly reproduces the characteristics of large-scale energy storage flywheel outer rotor motors

□ System Parameters

● Electromagnetic Drive System

Parameter	Value	Description
Operating Voltage	DC 12-100V	Rated Operating Voltage
Single Electromagnet Suction Force	0.5 kgf (4.9 N)	@DC12V, 25mm×20mm
Electromagnets per Pole	2 pcs	Symmetric Arrangement
Total Magnetic Poles	8 poles	Uniformly Distributed on Circumference, 45° Interval per Pole
Electromagnetic Air Gap	0.8 mm	Gap between Electromagnet and Flywheel Outer Edge
Air Gap Permeability Coefficient	1.25 mm^{-1}	$\eta=1/k$

● Mechanical Structure Parameters

Parameter	Value	Description
Flywheel Radius R	100 mm	Lever Arm Reference
Force Couple Arm	200 mm	Diameter, Torque Action Arm
Electromagnet Size	25mm×20mm	Single Electromagnet Outline Dimensions

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□ Electromagnetic Force Calculation

● Total Tangential Electromagnetic Force

$$F_t = \eta \times f \times n \times \alpha$$

● Parameter Definitions

Symbol	Value	Physical Meaning	Unit
η	1.25	Air Gap Permeability Coefficient, $\eta = 1/k$	mm^{-1}
k	0.8	Electromagnetic Air Gap Distance	mm
f	9.8	Electromagnetic Suction Force per Pole (Equivalent to 1 kgf, $2 \times 0.5 \text{ kgf}$)	N
n	8	Total Number of Magnetic Poles	pcs
nm	2 per	Number of Electromagnets per Pole	pcs
α	0.5	Effective Work Coefficient ($p/2$, only half of magnetic poles do tangential work)	---

□ Calculation Example (@DC12V)

● Total Tangential Electromagnetic Force Calculation

$$F_t = 0.81 \times 9.8 \times 8 \times 0.5 = 1.25 \times 9.8 \times 4 = 49 \text{ N}$$

● Output Torque Calculation

$$T = F_t \times 2R = 49 \text{ N} \times 0.2 \text{ m} = 9.8 \text{ N} \cdot \text{m}$$

Note:

Single electromagnet with 8 poles uniformly distributed (45° per pole), 2 electromagnets per pole arranged symmetrically, total 16 electromagnets forming 4 sets of symmetric force couples.

□ Eight-Pole Sequential Pulse Drive

- 8 magnetic poles uniformly distributed circumferentially, stepwise accelerating rotating magnetic field
- 8 steps per revolution, step angle 45° , smooth operation with low vibration
- Frequency 10-400Hz stepless adjustment, precise speed control

□ Technical Parameters

● Mechanical System

Parameter	Specification	Description
Flywheel Diameter	$\varnothing 200 \text{ mm}$	High-strength Aluminum Alloy, Dynamic Balance G2.5 Grade
Tuo code counterweight system	5 kg + 3kg + 2kg	Modular Combination, Moment of Inertia 0.025-0.25 $\text{kg} \cdot \text{m}^2$ Adjustable
Magnetic Pole Configuration	Single-stage 8 poles	Voltage-regulated Electromagnetic Coil, $\varnothing 25 \text{ mm}$
Lever Action Angle	$45^\circ (\pi/4)$	Optimized Torque Transfer Efficiency
Air Gap Adjustment	0.2-2 mm	Adaptable to Different Experimental Requirements
Overall Dimensions	600×600×400 mm	Laboratory Desktop Design
Overall Weigh	~380 kg	Stable Anti-vibration Base

● Electrical Drive

Parameter	Specification	Description
Drive Voltage	DC 12-100 V	Wide Range Adjustable, Compatible with Multiple Power Sources
Pulse Frequency	10-400 Hz	Corresponding to Speed 1.25-3000 RPM
Positive Pulse Width	1-20 ms	Energy Injection Time Adjustable
Negative Pulse Width	1 ms	Fixed Freewheeling/Braking
Peak Power	1.5 kW	Meeting Acceleration and Steady-state Requirements
Input Power Supply	AC100-240V	Wide Voltage Global Universal

● Motion Performance

Parameter	Specification	Description
Speed Range	10-3000 RPM	Covering Low-speed Debugging to High-speed Energy Storage
Rated Speed	600 RPM	Standard Teaching Operating Condition
Maximum Linear Velocity	31.4 m/s	Edge Linear Velocity at 3000 RPM
Angular Velocity	1.05-314 rad/s	Wide Range Dynamic Response
Angular Acceleration	0.02-2 rad/s ²	Precise Acceleration Control
Startup Time	<5 s (0-600 RPM)	Rapid Establishment of Experimental Conditions

● Measurement and Control System

Parameter	Specification	Description
Speed Detection	Hall Sensor + Magnetic Cone	8 Pulses/Revolution, Non-contact Measurement
Waveform Analysis	Tektronix/TDS7404B	100MHz, Four-channel Real-time Observation 100MHz
Electrical Measurement	HAMEG HM1507-3	Voltage/Current/Frequency/Duty Cycle
Speed Display	4-digit LED Digital Tube	Intuitive RPM Reading
Safety Protection	GH19C Intelligent System	Five-fold Protection: Overspeed/Overcurrent/Overtemperature/Vibration/Displacement

• Ten-Dimensional Experimental Variables

No.	Variable Name	Symbol	Adjustment Range	Experimental Significance
1	Weight Mass	m	2--10 kg	Moment of Inertia J Adjustment
2	Electromagnetic Force	F	0--500 N	Drive Torque $T=F \cdot R$
3	Drive Voltage	V	12--100 V	Control Excitation Current
4	Drive Current	I	0--15 A	Electromagnetic Force Excitation Source
5	Pulse Frequency	f	10--400 Hz	Speed Setting
6	Positive Pulse Width	t+	1--20 ms	Energy Injection Duration
7	Angular Acceleration	α	Measured Value	Dynamic Response Output
8	Magnetic field displacement angle	θ	$\pm 7--13.5^\circ$	Optimal Action Angle
9	Magnetic Induction Intensity	B	0--1.2 T	Proportional to Current
10	Flywheel Phase	(x,y)	$[0,2\pi]^2$	State Space Variable

□ Core Experimental Functions

Basic Physics Experiments

- **Verification of Rotation Law:** $\tau = J\alpha$, linear relationship between torque and angular acceleration
- **Moment of Inertia Measurement Experiment:** Comparison between theoretical calculation and measured values
- **Energy Conservation Demonstration:** Conversion between electrical energy \rightarrow kinetic energy \rightarrow electrical energy

Motor Drive Experiments

- **Switched Reluctance Motor Principle:** 8-pole sequential same-phase mechanism
- **Mechanical Characteristic Curve:** Three-dimensional relationship of speed-torque-efficiency
- **PWM Control Technology:** Pulse width modulation and duty cycle optimization

Energy Storage System Experiments

- **Charge-Discharge Cycle:** Energy storage and release efficiency analysis
- **Dynamic Response Test:** Step/ramp/disturbance response
- **Braking Energy Recovery:** Comparison between energy consumption braking and reverse connection braking

Advanced Research Experiments

- **Multi-variable Coupling Analysis:** Nine-dimensional parameter orthogonal experimental design
- **Edge Drive Optimization:** Collaborative optimization of air gap/angle/frequency
- **Model Identification and Verification:** Comparison between theoretical mathematical modeling and experiments

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□ Target Users

User Type	Application Scenario	Value Proposition
Universities and Colleges	Physics/Electrical/Energy Professional Experimental Teaching	Filling the Gap in Flywheel Energy Storage Experimental Equipment, Combining Theory with Practice
Vocational Colleges	New Energy Technology Practical Training	Mastering Energy Storage System Installation, Debugging and Maintenance Skills
Scientific Research Institutes	Flywheel Energy Storage Mechanism and Control Research	Providing Repeatable Precision Experimental Platform
Enterprise R&D	Motor Drive and Energy Management Pre-research	Low-cost Verification of Innovative Solution Feasibility

□ Product Advantages

Comparison Item	Traditional Experimental Devices	GH103
Drive Mode	Shaft-center Motor Drive	Edge Magnetic Pole Drive, Torque 4-8× Larger
Parameter Adjustment	Fixed Parameters, Single Experiment	Nine-dimensional Adjustable, Flexible Experimental Design
Measurement Means	Mechanical/Simple Electronic	Hall Sensor + Digital Oscilloscope, Precision Acquisition
Safety Protection	Basic Protection	GH19C Five-fold Intelligent Protection, Safe and Reliable GH19C
Expansion Capability	Closed Structure	Modular Design, Supporting Multi-level Expansion and Vacuum Upgrade

□ Standard Configuration

- ✓ GH103 Main Unit (Flywheel Rotor, 8-pole Drive, Control System, Protective Cover)
- ✓ Weight Block Set (Flywheel Weights: 5kg×1, 3kg×1, 2kg×1, with Quick Locking Mechanism)
- ✓ Tektronix TDS7404B Digital Oscilloscope (100MHz, Four-channel)
- ✓ HAMEG HM1507-3 Multifunction Measuring Instrument
- ✓ Hall Sensor Kit (8 Sets, Including Magnetic Cones)
- ✓ Electrical Connection Harness (Power Cables, Signal Cables, BNC Cables)
- ✓ Operation Manual (Including Experimental Guidance and Theoretical Derivation)
- ✓ Factory Inspection Certificate and Warranty Card

□ Optional Extensions

Option	Function Description	Application Scenario
Vacuum Chamber Kit	Stainless Steel Vacuum Cover + Vacuum Pump, Vacuum Degree ≤100Pa	High-speed Low Wind Resistance Experiment, Wind Loss Mechanism Research
Secondary Expansion Module	Additional 8 Magnetic Poles, 16-pole Configuration	High-resolution Step Drive, Micro-vibration Analysis
Data Acquisition System	16-bit USB-DAQ, 4-channel Synchronization, Supporting Software	Automated Experimental Recording, Large Data Volume Acquisition
Temperature Monitoring Module	8-channel PT100 Temperature Sensors, Magnetic Pole Thermal Management 8路 PT100	Long-term Operation Thermal Characteristics Research, Efficiency Optimization
Ceramic Bearing Upgrade	High-speed Bearings, Supporting 5000 RPM Extension	Ultra-high-speed Energy Storage Experiment, Limit Performance Testing

□ **Service Commitment**

Service Item	Content
Warranty Period	Whole Machine 1 Year, Controller and Driver 3 Years
Installation and Commissioning	Free On-site Installation, Commissioning, Operation Training
Technical Support	7×24 Hours Telephone Support, Remote Diagnosis, On-site Service
Software Upgrade	Continuous Optimization of Control Algorithms, Lifetime Free Upgrade
Custom Development	Customizing Parameters and Developing Exclusive Experimental Solutions According to Special Requirements

□ **Technical Specification Quick Reference Table**

Key Indicators	Value
Flywheel Diameter	200 mm
Speed Range	10-3000 RPM
Drive Voltage	12-100 V
Peak Power	1.5 kW
Moment of Inertia	0.025-0.25 kg·m ²
Angular Acceleration	0.02-2 rad/s ²
Overall Weight	~380 kg
Protection Grade	IP20

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GH103 Flywheel Energy Storage Experimental System——Transforming Abstract Energy Storage Theory into Intuitive Experimental Data. Innovative Edge Drive, Opening a New Era of Energy Storage Teaching.