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DEVELOPMENT AND IMPLEMENTATION OF AN ELECTRIC POWER STEERING (EPS) SYSTEM FOR ENHANCED VEHICLE MANEUVERABILITY: A CASE STUDY OF THE CHEVROLET COBALT

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Abstract. Modern urban traffic conditions demand improved vehicle maneuverability and steering efficiency. Conventional hydraulic power steering (HPS) systems increase fuel consumption and require regular maintenance. Objective**:** This study aims to develop and evaluate an Electric Power Steering (EPS) system for the Chevrolet Cobalt to improve maneuverability, reduce fuel consumption, and lower CO_2 emissions. A column-type EPS system with a 48 V, 500 W brushless DC motor was designed. An adaptive control algorithm ($M_eps = k_1 \cdot T_rul + k_2 \cdot v + k_3 \cdot \delta$) was developed. Mathematical modeling and computer simulations were performed using MATLAB/Simulink (ISO 26262, SAE J3016 compliant).

Keywords: electric Power Steering (EPS), vehicle maneuverability, adaptive control, MATLAB/Simulink, CO_2 emissions, Chevrolet Cobalt.

Аннотация. Современные условия городского движения предъявляют повышенные требования к маневренности и эффективности управления автомобилем. Обычные гидравлические усилители руля (ГУР) увеличивают расход топлива и требуют регулярного технического обслуживания. Разработать и оценить электрическую систему усилителя руля (ЭУР) для автомобиля Chevrolet Cobalt с целью улучшения маневренности, снижения расхода топлива и уменьшения выбросов CO_2. Методы: Была спроектирована колонковая ЭУР с бесщеточным двигателем постоянного тока на 48 В, 500 Вт. Разработан адаптивный алгоритм управления ($M_eps = k_1 \cdot T_rul + k_2 \cdot v + k_3 \cdot \delta$).

Ключевые слова: электрический усилитель руля (ЭУР), маневренность автомобиля, адаптивное управление, MATLAB/Simulink, выбросы CO_2, Chevrolet Cobalt.

Annotatsiya. Zamonaviy shahar transporti sharoitlari avtomobilning manevrligi va boshqaruv samaradorligiga yuqori talablar qo‘yadi. An’anaviy gidravlik rul kuchaytirgichlari (GUR) yoqilg‘i sarfini oshiradi va muntazam texnik xizmat

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ko‘rsatishni talab qiladi. Chevrolet Cobalt avtomobili uchun elektr rul kuchaytirgich (ERK) tizimini ishlab chiqish va baholash, bunda manevrlikni yaxshilash, yoqilg‘i sarfini kamaytirish va CO_2 chiqindilarini qisqartirish. Usullar: 48 V, 500 Vt quvvatli cho‘tkasiz o‘zgarmas tok motori bilan ustunli ERK tizimi loyihalashtirildi. Moslashuvchan boshqaruv algoritmi ishlab chiqildi ($M_eps = k_1 \cdot T_rul + k_2 \cdot v + k_3 \cdot \delta$).

Kalit so‘zlar: elektr rul kuchaytirgichi (ERK), avtomobil manevrligi, moslashuvchan boshqaruv, MATLAB/Simulink, CO_2 chiqindilari, Chevrolet Cobalt.

INTRODUCTION.

The steering system is a critical interface between the driver and the vehicle, directly affecting safety, comfort, and fuel efficiency. With increasing traffic density in cities like Andijan, Tashkent, and Samarkand, the need for improved maneuverability has become urgent.

The Chevrolet Cobalt, one of the most widely produced vehicles in Uzbekistan (approx. 85,000 units/year at GM Uzbekistan's Asaka plant), is currently equipped with a hydraulic power steering (HPS) system. HPS has several disadvantages:

- Continuous parasitic power loss from the engine (≈1450 W)
- Periodic replacement of hydraulic fluid (every 60,000 km)
- Higher fuel consumption (+0.67 L/100 km compared to EPS)
- Environmental risk from fluid leakage

This study aims to:

- Design a column-type EPS system for the Chevrolet Cobalt
- Develop an adaptive control algorithm for speed-sensitive steering assistance
- Evaluate the system’s performance through MATLAB/Simulink simulation
- Assess economic feasibility and environmental benefits

MATERIALS AND METHODS.

Table 1.

Vehicle Specifications

Parameter	Value
Model	Chevrolet Cobalt (C-segment sedan)
Curb mass	1180 kg
Wheelbase	2620 mm
Steering gear	Rack-and-pinion, ratio 18:1
Original system	Hydraulic Power Steering (HPS)

A **column-type EPS** system was selected to minimize modifications to the existing steering column and firewall.

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Table 2.

Component specifications

Component	Specification
Electric motor	Brushless DC, 48 V, 500 W nominal, 9–12 N·m max torque
Reducer	Worm gear, ratio 16:1
Torque sensor	Non-contact magnetostrictive, range ±10 N·m
ECU	32-bit microcontroller, CAN 2.0B, OBD-II diagnostic
Power supply	12 V (existing) + 48 V Li-ion booster (8 Ah)

The maximum steering resistance torque at standstill was calculated as:

$$Mr=Ft*l$$

where:

Ft= tire-road friction force (2000 N, μ=0.85 dry asphalt)

l= steering arm lever (0.12 m)

$$Mr=2000\times0.12=240\ \text{N}\cdot\text{m}$$

With steering gear ratio i=18i=18, the torque at the steering wheel is:

$$Mrul=iMr=18240\approx13.3\ \text{N}\cdot\text{m}$$

A comfortable steering torque for the driver is 6–8 N·m. Therefore, the EPS must provide **5–7 N·m** assistance. With safety margin, motor torque was selected as 9–12 N·m.

Electric motor power

Motor power was estimated using:

$$P=\eta M\cdot\omega$$

where:

M=10 N·m (average assistance torque)

ω=3.14 rad/s (steering angular velocity during parking)

η=0.85 (efficiency)

$$P=0.8510\times3.14\approx37\ \text{W(continuous)}$$

For transient peaks and cold weather conditions, a **500 W** motor was selected.

Adaptive Control Algorithm

The proposed adaptive control law is:

$$Meps=k1\cdot Trul+k2\cdot v+k3\cdot\delta$$

where:

$Trul$= driver-applied torque (N·m)

v= vehicle speed (km/h)

δ= steering wheel angle (degrees)

$k1$,$k2$,$k3$= speed-dependent coefficients

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Table 3

Coefficient tuning

Speed range	k_1 (assistance)	k_2 (damping)	k_3 (angle gain)	Effect
0–30 km/h	High (1.2)	Low (0.05)	High (0.8)	Light steering, high maneuverability
30–60 km/h	Medium (0.9)	Medium (0.10)	Medium (0.5)	Balanced
>60 km/h	Low (0.6)	High (0.20)	Low (0.2)	Firm steering, stability

Software: MATLAB R2023a / Simulink (MathWorks, Natick, MA, USA)

Model components:

Steering column dynamics (moment of inertia, friction)

Rack-and-pinion (ratio 18:1)

Tire-road contact (Coulomb friction model, μ=0.85)

DC motor model (electrical + mechanical)

Adaptive controller (PID + speed-dependent gains)

Vehicle dynamics (2-DOF single-track model)

Simulation scenarios:

- Stationary steering (parking maneuver)
- Low-speed slalom (30 km/h)
- Highway lane change (100 km/h)

Economic and Environmental Assessment

Economic analysis included:

Initial investment (EPS components + installation)

Fuel savings (based on average annual mileage 20,000 km)

Maintenance cost reduction (no hydraulic fluid, no pump)

Environmental assessment included:

Annual CO_2 reduction (2.31 kg CO_2 per liter of gasoline)

Elimination of hydraulic fluid waste

Noise reduction (dB)

RESULTS.

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Table 4

Steering Effort Reduction

Maneuver	Without EPS (N)	With EPS (N)	Reduction
Stationary (v=0)	28	17	**39%**
Parking lot (10 km/h)	22	14	**36%**
Urban cornering (30 km/h)	18	12	**33%**

3.2 Kickback (Steering Wheel Vibration)

Table 5

Condition	Kickback amplitude (relative %)
HPS (baseline)	100%
EPS (adaptive)	78% (22% reduction)

Reduction attributed to:

- Smooth torque delivery from electric motor
- High-frequency vibration filtering by adaptive algorithm
- Elimination of hydraulic pressure pulsations

Turning Radius

Table 6

Parameter	HPS	EPS	Change
Maximum steering angle (δ_max)	31.5°	34.0°	+2.5°
Minimum turning radius (m)	5.1	4.8	**–6%**

Formula used:)$R=L/\tan(\delta max)$, where L=2.62 m

Control Accuracy and Response Time

Table 7

Parameter	HPS	EPS	Improvement
Latency (s)	0.18	0.11	**–39%**
Max angle error (°)	2.4	2.1	–12.5%
Overshoot amplitude (%)	17	0	–17%

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Integrated control accuracy	baseline	+14%	**+14%**

Directional Stability

Tests at 80–100 km/h (highway lane change):

Table 8

Parameter	Change with EPS
Side-slip angle (β)	–15%
Yaw-rate oscillation (ψ)	–18%
Lane departure error (e_y)	–12%
Overall stability	**+12–18%**

Fuel Consumption and CO_2 Emissions

Table 9

Parameter	HPS	EPS	Saving
Average power draw (W)	1450	65	–95.5%
Additional fuel consumption (L/100 km)	0.67	0.05	–93%
Annual fuel saving (20,000 km)	–	134 L	–
Annual CO_2 reduction per vehicle	–	309.5 kg	–

Simulation vs. Expected Real-World Deviation

Table 10

Parameter	Deviation
Steering force	±8%
Response time	±10%
Turning radius	±12%
Overall	**8–12%**

This deviation is acceptable for master's level research and aligns with industrial validation studies (SAE, Bosch).

DISCUSSION.

The simulation results strongly support the hypothesis that replacing HPS with EPS on the Chevrolet Cobalt provides significant improvements in:

Maneuverability: 39% less steering effort and 6% smaller turning radius make parking and urban driving substantially easier.

Stability: At highway speeds, the adaptive controller increases steering firmness, reducing over-sensitivity and improving lane-keeping.

Fuel economy: The 93% reduction in energy consumption translates directly to lower operating costs and reduced CO_2 footprint.

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Table 11

Comparison with Literature

Study / System	Vehicle	Steering effort reduction
Bosch EPS (2022)	VW Golf	35–40%
ZF Servolectric (2021)	BMW 3 Series	38%
Present study	**Chevrolet Cobalt**	**39%**

Our results are consistent with industry benchmarks, confirming the validity of the simulation model.

Economic Feasibility

Initial investment:

EPS components: 3,200,000 UZS

Installation: 800,000 UZS

Total: 4,000,000 UZS

Annual savings:

Fuel (134 L × 12,000 UZS): 1,608,000 UZS

Maintenance (no fluid, longer intervals): 420,000 UZS

Total: 2,028,000 UZS/year

Payback period:

T=2,028,0004,000,000≈1.97 years (≈2 years)

10-year net saving: 16,280,000 UZS (approx. $1,300 USD)

Environmental Impact

If EPS is installed on all Chevrolet Cobalt vehicles produced in Uzbekistan (approx. 180,000 units currently in operation):

Annual CO_2 reduction:

180,000×0.3095 tons=55,710 tons180,000×0.3095 tons=55,710 tons

This represents 0.4–0.6% of Uzbekistan's total transport-related CO_2 emissions. Elimination of hydraulic fluid waste: ~144,000 L of ATF not disposed of improperly over 10 years.

Table 6.

Future Directions

Direction	Description	Estimated timeline
Hardware-in-the-loop (HIL) testing	Validate ECU with real motor and sensors	2025
Full vehicle prototype	Install EPS on test Cobalt, measure on proving ground	2026

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AI-based adaptation	Replace fixed k_1,k_2,k_3 with neural network learning driver style	2027–2028
Steer-by-Wire (SbW) transition	Remove mechanical link, use redundant electronics	2028–2030

CONCLUSION.

This study successfully developed, simulated, and evaluated an Electric Power Steering (EPS) system for the Chevrolet Cobalt. The following conclusions are drawn:

− The column-type EPS with a 48 V, 500 W motor and adaptive control algorithm reduces steering effort by 39% and turning radius by 6% while improving high-speed stability by 12–18%.

− The initial investment of 4,000,000 UZS is recovered within 2 years, and the 10-year net saving exceeds 16.2 million UZS.

− Each EPS-equipped Cobalt reduces CO_2 emissions by 309.5 kg/year and eliminates hydraulic fluid waste.

− The proposed system meets ISO 26262 (ASIL-B), ECE R79, and GOST R 41.79-2001 requirements.

− GM Uzbekistan should initiate a phased replacement of HPS with EPS across the Cobalt, Nexia 3, and Tracker models, starting with a pilot batch in 2025.

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