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## RESEARCH ARTICLE

# Comparison Survey of Effects of Hull on AUVs for Underwater Capacitive Wireless Power Transfer System and Underwater Inductive Wireless Power Transfer System

LEI YANG<sup>1</sup>, (Senior Member, IEEE), YUANQI ZHANG<sup>1</sup>, XAOJIE LI<sup>1</sup>, BAOXIANG FENG<sup>1</sup>,  
XINZE CHEN<sup>1</sup>, JINGJING HUANG<sup>2</sup>, (Member, IEEE), TING YANG<sup>3</sup>,  
DARUI ZHU<sup>1</sup>, (Member, IEEE), AIMIN ZHANG<sup>2</sup>, (Member, IEEE),  
AND XIANGQIAN TONG<sup>1</sup>, (Member, IEEE)

<sup>1</sup>School of Electrical and Engineering, Xi'an University of Technology, Xi'an, Shaanxi 710048, China

<sup>2</sup>School of Automation Science and Engineering, Xi'an Jiaotong University, Xi'an 710049, China

<sup>3</sup>School of Energy Engineering, Yulin University, Yulin 719000, China

Corresponding author: Lei Yang (yanglei0930@xaut.edu.cn)

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**ABSTRACT** Underwater wireless power transfer (UWPT) system has attracted widespread attention. It has been used for power delivery for underwater equipment in the marine environment with high safety and convenience. However, the material of metal plates and the shape which will affect the high frequency alternating electromagnetic fields and the high frequency alternating electric fields for the inductive wireless power transfer (IPT) system and the capacitive wireless power transfer (CPT) system. This paper presents the effects of the hull of the autonomous underwater vehicle (AUV) on the underwater wireless power transfer system including the underwater capacitive wireless power transfer (UCWPT) system and underwater inductive wireless power transfer (UIWPT) system. The features of underwater wireless power transfer systems have been carefully studied with simulation and experimental work. The experimental water tank has been constructed with the 35‰ salinity water. The hull of AUVs has been respectively simulated and built with rectangle metal plates and curved metal plates. The original experimental data and phenomenon have been presented in this paper. The different performance of the UCWPT system and UIWPT system is provided and discussed in this paper. The comparison work with the related paper has been analyzed. This paper could be acted as the reference for designing the underwater wireless power transfer system for AUVs.

**INDEX TERMS** Underwater wireless power transfer (UWPT), capacitive, material, shape, autonomous underwater vehicles (AUVs).

## I. INTRODUCTION

An autonomous underwater vehicle (AUV) is an unmanned submersible vehicle that could operate autonomously. AUVs have been widely used for exploring marine resources and

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monitoring infrastructure facilities. Most of them are powered by batteries such as lithium batteries and lead-acid cells. Generally, there are two recharging methods. One is that it needs to be lifted out of the water to change the battery or recharge. The other one is that it is recharged with the physical wire which is put deep down to the AUVs in the marine environment. Their autonomy and work efficiency are quietly

limited by the umbilical cable. The mother ship platform should be cruising around to provide the main technical and energy support.

The underwater wireless power transfer method could provide a convenient and safety energy supply for AUVs [1], [2], [3]. The power could be transferred from the wireless charging station to the AUVs without the physical wire restriction. The degree of freedom is greatly increased. Work efficiency is highly improved with the WPT technology. The sparks will not occur in the conducted marine environment without the plug-in and plug-out operation. The corrosion problems triggered by the seawater will also not have happened without the physical wire and the plug and socket.

As shown in Fig. 1, it is a model for the underwater wireless power transfer system. The underwater wireless charging power transfer station could not only recharge the AUVs but also the underwater sensors. The power could be wirelessly transferred with the inductive wireless power transfer method based on the high-frequency alternating electromagnetic field and the capacitive wireless power transfer system based on the high-frequency alternating electric field. With wireless charging technology, the AUVs could effectively prolong the attended time and extend the endurance mileage.

As the most promising underwater power feeding technique, the underwater inductive wireless power transfer technology meets intractable challenges such as eddy current loss, frequency splitting, magnetic waveforms attenuation in seawater, and ocean current disturbance, etc [4]. For the inductive wireless power transfer method, there are different kinds of coil structures, energy, power loss models, and control methods that have been proposed for marine applications. Z. Yan, et.al, [5] proposed a rotation-free wireless power transfer system based on a new coil structure to achieve stable output power and efficiency against rotational misalignments for charging autonomous underwater vehicles. J. Kim, et.al, proposed an efficient modeling for the UWPT system using Z-parameters. Utilizing the electromagnetic analysis and two port network analysis, it could build an impedance model of coils considering the frequency and the conductivity of seawater [6]. R. Hasaba, et.al. designed a wireless magnetic resonance-based power transfer system with multiple coils using the bandpass filter (BPF) theory [7]. The coil structure is sealed so that the water cannot enter it. The results confirm wireless power transfer exceeding 10 m in an undersea setting. The maximum transfer is about 100 W. The coil structure is considered to achieve high efficiency and low power loss. The eddy current loss is detailed and analyzed in [8] and [9] to provide the design guidance for underwater inductive wireless power transfer systems. A multi-transmitter multi-receiver (MT-MR) WPT system was presented in [10] for the application of the submerged buoy with the maximum efficiency tracking method, and a number of beacons could be charged at the same time to send more data. L. Yang, et.al, described a new design method to deal with the misalignment and the changeable distance between the transmitter side

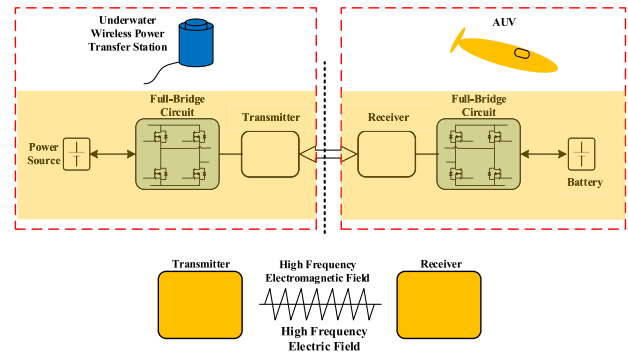


FIGURE 1. Underwater wireless power transfer system.

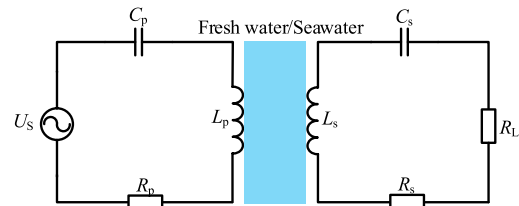


FIGURE 2. Model of the underwater inductive wireless power transfer system.

and receiver side of the UWPT system to get stable load regulation with the one-cycle control method [11]. It adapts the switched capacitor (SC) converter acting as the boost DC-DC converter. Recently, a novel arc-shaped lightweight magnetic coupler for AUV wireless power transfer has been presented in [12]. The 3 kW power level experimental setup was built and tested with the highest DC-DC efficiency of 91.9% at the forward maximum output power point. The Fe-based nanocrystalline alloy soft magnetic material acted as the magnetic core to set up an arc-shaped inductive wireless power transfer structure.

The capacitive wireless power transfer (CPT) system has been used as a wireless charging method for electrical vehicles, mobile devices, and so on [13], [14], [15], [16], [17], [18], [19]. It could act as an alternative near-field power transfer method to well-known magnetic field-based approaches. One of the most attractive advantages of the capacitive-based WPT is the avoidance of undesired eddy currents and electromagnetic interferences (EMI) that come with magnetic-based WPT methods [20]. In the marine environment, the hull will have more impact on the power transfer and the electromagnetic fields or the electric fields for the conductive feature of seawater which is compared with the air medium [3], [4], [21], [22], [23], [24], [25]. In addition to efficiency improvements, capacitive wireless power transfer systems are potential with lower volume and construction complexity.

Recently, the CPT system has been adapted for marine environment applications. Paper [25] presented the design of a capacitive wireless power transfer system for operation in fresh water. Paper [20] investigated the underwater capacitive wireless power transfer technology for the electric ship charging application. It shows that the underwater capacitive wireless power transfer system could provide the

high-power capability up to MW level, which is sufficient to charge the electric ship rapidly. The bidirectional underwater capacitive wireless power transfer system (BD-UCWPT) for autonomous underwater vehicles (AUVs) was presented in [26]. The maximum available power and the corresponding efficiency were tested with the variable operating frequency in [19].

Paper [27] proposed a coil structure design method that is compatible with the structure of the AUVs and the rotational misalignment method for stabilizing the output power of an underwater wireless power transfer system. Paper [28] presented a four-plate underwater capacitive wireless power transfer system with rectangular coupled structure plates. Paper [29] studied the feasibility of wireless charging for AUVs with novel pressure-resistant ceramics and made a comparison with a glass hull. However, the underwater wireless power transfer system rarely considers the impact of the compatibility of the coil structure and the hull of the AUVs, which can highly affect the hydrodynamic performance of the AUVs.

Compared with the arc-shaped lightweight magnetic coupler which is suitable for the underwater inductive wireless power transfer system [12], this work presents the effects of the hull of AUVs on the underwater wireless power transfer system including the underwater inductive wireless power transfer system and the underwater capacitive wireless power transfer system with the curved coupled metal plates which is suitable for the cylindrical AUVs. The different performances of the underwater inductive wireless power transfer system and the underwater capacitive wireless power transfer system are carefully compared in this work. The impact of the metal hull on AUVs is analyzed and tested in this paper. A rectangle and curved hull-compatible metal plate structure are also studied in this paper to provide the reference for the underwater inductive wireless power transfer system and the capacitive wireless power transfer system.

The rest of the paper is organized as follows: the coupled structure is shown in Section II. Section III provides the theoretical analysis. The simulated and experimental verification is shown in Section IV. The conclusions and discussions are drawn in Section V.

## II. COUPLING STRUCTURE AND THEORY ANALYSIS

### A. FOR UNDERWATER INDUCTIVE WIRELESS POWER TRANSFER SYSTEM

In this paper, the underwater inductive wireless power transfer system based on electromagnetic fields is analyzed in the marine environment. For the underwater inductive wireless power transfer system, the coupled structure could be designed with the inductive coil and the model is shown in Fig.2.

In the marine environment, the total resistance of a coil in air, freshwater, or seawater consists of DC resistance, AC resistance, and radiation resistance. The radiation

resistance in seawater or freshwater could be written as:

$$R_{rad}^M = \omega \mu_M R l \left[ \frac{4}{3} (\beta R)^2 - \frac{\pi}{3} (\beta R)^3 + \frac{2\pi}{15} (\beta R)^5 - \dots \right] \quad (1)$$

where  $\omega$  is the angular frequency,  $\beta = \sqrt{\frac{\mu_M \omega \sigma_M}{2}}$ , and  $\sigma_M$  is the conductivity of seawater or freshwater and  $R$  is the radius of the coil loop in meters.

According to [30], [31], [32], the primary side equivalent resistance of the underwater inductive wireless power transfer system could be written as:

$$R_P = R_{DC}^M + R_{AC}^M + R_{rad}^M + R_1 \quad (2)$$

where  $R_{DC}^M$  is the DC resistance of the coil in the seawater or freshwater and  $R_{AC}^M$  is the AC resistance of the coil in seawater or freshwater.

The secondary side equivalent resistance of the UIPT system could be calculated as:

$$R_S = R_{DC}^M + R_{AC}^M + R_{rad}^M + R_2 \quad (3)$$

Due to the coils' skin depth [3], [23], the AC resistance could be written as:

$$R_{AC}^M = \frac{l \times \rho}{\pi \times \omega \times \delta} \quad (4)$$

where  $l$  is the wire length of coil,  $\rho$  is electric resistivity, and  $\delta$  is skin depth,  $\delta = \sqrt{\frac{2\rho}{\omega \mu_M}}$ .

Based on the aforementioned discussion, the mutual inductance between Tx and Rx could be written as:

$$L_M = \frac{\mu_0 \sigma}{4\pi} N_P N_S \iint \frac{e^{-\gamma |R_S - R_P|}}{|R_S - R_P|} dl_P dl_S \quad (5)$$

where  $\gamma \approx \sqrt{j\omega \mu_0 \delta}$ ,  $N_P$  and  $N_S$  are respectively turns ratio of transmitter coil and turns ratio of receiver coil,  $R_P$ , and  $R_S$  are respectively equivalent resistance of primary side and the secondary side.  $\sigma$  is the conductivity of the medium,  $l_P$  and  $l_S$  are respectively perimeters of the two coils.

Considering (5), the coupling coefficient is derived as:

$$k_M = \frac{L_M}{\sqrt{L_P L_S}} = \frac{\frac{\mu_0 \sigma}{4\pi} N_P N_S \iint \frac{e^{-\gamma |R_S - R_P|}}{|R_S - R_P|} dl_P dl_S}{\sqrt{L_P L_S}} \quad (6)$$

The high-frequency alternating currents in the coil could generate the eddy current loss in freshwater or seawater condition. Based on [8], the eddy current loss could be presented as:

$$P_{eddy-M} \approx \frac{2\omega^2 |B_a|^2 \pi D R^4 \sigma_M}{3} \quad (7)$$

where  $B_a$  is average magnetic flux density.

The load voltage, coupling coefficient, and angular frequency of Tx or Rx have a relationship as:

$$V_L = \frac{j\omega K_{t/r} \frac{1}{R+j\omega L + \frac{1}{j\omega C}} V_R R_L}{j\omega L + R_o + R_L + \frac{1}{j\omega C} + \omega^2 K_{t/r}^2 L^2 \frac{1}{(R_e + j\omega L + \frac{1}{j\omega C})}} \quad (8)$$

where  $V_L$  is load voltage,  $R_o$  is the internal resistance of  $T_x$  or  $R_x$ ,  $R_L$  is load resistance,  $V_R$  is voltage of  $R_x$ ,  $R_e$  is equivalent resistance of  $T_x$  or  $R_x$ .

The relationship between voltage of receiver and the voltage of transmitter could be derived as:

$$V_R = \frac{(\omega L_M)R_L}{(R_L + R_R)[R_T R_R + (\omega L_M)^2]} V_T \quad (9)$$

Considering (4), the quality factor of a coil could be derived as:

$$Q = \frac{\omega L}{R_{AC}} = \frac{\pi \omega^2 \delta L}{l \rho} \quad (10)$$

The output power of the UIPT system could be expressed as:

$$P_o = \frac{\omega I_1^2 L_M Q_2}{R_L} \quad (11)$$

where  $I_1$  is the current of the transmitter coil,  $Q_2$  is the quality factor of the receiver coil and  $R_L$  is the load resistance.

Considering (4) and (9), (11) could be rewritten as:

$$P_o = \frac{\pi \delta \omega^3 I_1^2 L_S L_M}{\rho l S R_L} \quad (12)$$

### B. FOR UNDERWATER CAPACITIVE WIRELESS POWER TRANSFER SYSTEM

The underwater capacitive wireless power transfer system based on the electric fields is also analyzed under the marine environment in this paper. For the underwater capacitive wireless power transfer system, the coupled structure which is designed with the curved coupled metal plates is shown in Fig.3 with the metal material such as iron, aluminum, and copper.

In the seawater condition, the permittivity of seawater determines the capacitance of the coupling capacitor. The permittivity of seawater, temperature, salinity, and angular frequency of electromagnetic wave have a relationship as:

$$\varepsilon_{sea}(s, t, \omega) = \varepsilon_{\infty}(s, t) + \frac{\varepsilon_1(s, t) - \varepsilon_{\infty}(s, t)}{1 - j\omega\tau(s, t)} - j \frac{\delta(s, t)}{\omega\varepsilon_0} \quad (13)$$

where  $\varepsilon_{\infty}(s, t)$  is the high-frequency seawater dielectric permittivity limit,  $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m is the permittivity of free space, the angular frequency of electromagnetic wave  $\omega = 2\pi f$ ,  $f$  is the frequency of electromagnetic wave,  $\varepsilon_1(s, t)$  is the static permittivity of seawater and  $\delta(s, t)$  is the ionic conductivity of seawater.

Considering the edge effects, with the seawater medium, the value of two coupling capacitor could be calculated as:

$$C = (1 + 2.343 \times (\frac{D}{l})^{0.89l}) \times (\varepsilon_{sea} \times \frac{l}{D}) \quad (14)$$

where  $l$  is the length of metal plate,  $D$  is the distance of one pair of plates, and  $\varepsilon_{sea}$  is the permittivity of seawater.

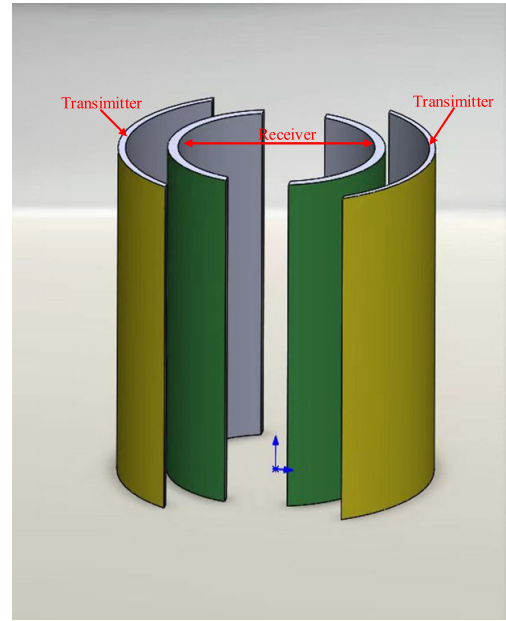


FIGURE 3. Model of curved capacitive coupled structure.

With the single-phase full-bridge inverter, the resonant voltage of the primary side could be derived as:

$$v_p = \frac{2\sqrt{2}}{\pi} v_{in} \quad (15)$$

On the other hand, with the single-phase full-bridge diode rectifier, the resonant voltage of the secondary side and the load voltage has a relationship as:

$$v_o = \frac{2\sqrt{2}}{\pi} v_s \quad (16)$$

There is an equivalent capacitor between every two metal plates, the six equivalent capacitors could be achieved in the coupling structure.

Based on the coupling capacitor structure model, the self-capacitance of primary side and self-capacitance of secondary side are expressed as follows:

$$C_p = C_{12} + \frac{(C_{13} + C_{14}) \times (C_{23} + C_{24})}{C_{13} + C_{14} + C_{23} + C_{24}} \quad (17)$$

$$C_s = C_{34} + \frac{(C_{13} + C_{23}) \times (C_{14} + C_{24})}{C_{13} + C_{14} + C_{23} + C_{24}} \quad (18)$$

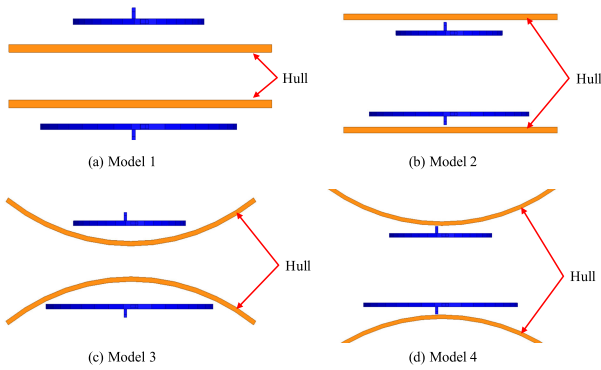
and, the mutual capacitance could be written as:

$$C_M = \frac{C_{13}C_{24} - C_{14}C_{23}}{C_{13} + C_{14} + C_{23} + C_{24}} \quad (19)$$

The resonant compensation network is a simple LC network. As a result, the resonant frequency could be derived as:

$$f_s = \frac{1}{2\pi \sqrt{L_p C_p}} = \frac{1}{2\pi \sqrt{L_s C_s}} \quad (20)$$

where  $L_p$  is the inductance of the equivalent inductor of the primary side resonant compensation network, and  $L_s$  is the



**FIGURE 4. Models of AUV hull and the coupling structure for underwater inductive wireless power transfer system.**

inductance of the equivalent inductor of the secondary side resonant compensation network.

The angular frequency is written as:

$$\omega_s = 2\pi f_s = \frac{1}{\sqrt{L_p C_p}} = \frac{1}{\sqrt{L_s C_s}} \quad (21)$$

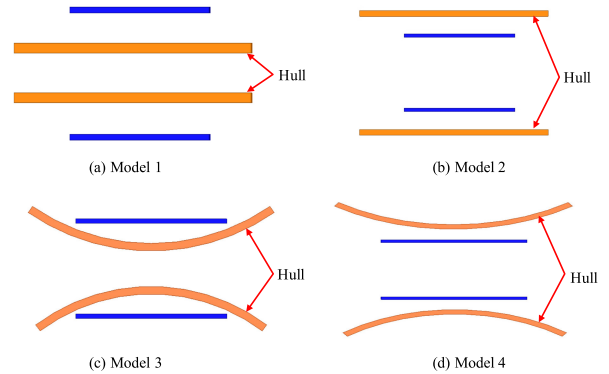
Considering the topology of the four-plate UCWPT system, the resonant voltage of the primary side  $v_p$  and the resonant voltage of the secondary side  $v_s$  have the relationship as:

$$v_s = \frac{j\omega C_p C_s}{C_M} v_p \quad (22)$$

### III. SIMULATED AND EXPERIMENTAL SURVEY

To survey the impact of the AUVs' hull on underwater wireless power transfer systems. The different models for the underwater inductive wireless power transfer systems and the underwater capacitive wireless power transfer system are constructed. The hull placement models for underwater inductive wireless power transfer system and for underwater capacitive wireless power transfer system are shown Fig.4 and Fig.5, respectively. For the deep understanding of the feature of the impact of the hull, the rectangle metal plates, and the curved metal plates are taken as examples. The inductive coupled structure and the capacitive coupler are respectively shown as Fig.4 and Fig.5. There are four placement models for inductive coupling structure and the capacitive coupler. A pair of rectangle metal plates and a pair of curved metal plates are respectively placed inside (Fig.4(a), Fig.4(c), Fig.5(a) and Fig.5(c)) and outside of the coupled structure (Fig.4(b), Fig.4(d), Fig.5(b) and Fig.5(d)). The simulation and experiments are conducted. The simulation work is done with the MATLAB software.

The different kinds of metal plates are adapted in the simulation and experimental for underwater inductive wireless power transfer system. The parameters for iron, copper and aluminum are shown as Table 1. The tested parameters of coils are shown as Table 2. The parameters of underwater inductive wireless power transfer system are surveyed for different placement models. The achieved data is shown as



**FIGURE 5. Models of AUV hull and the coupling structure for underwater capacitive wireless power transfer system.**

**TABLE 1. Parameters of different metal plates.**

Metal Plates	Conductivity	Permeability	Relative dielectric constant
Iron	10300000	4000	1
Copper	38000000	1.000021	1
Aluminum	58000000	0.999991	1

**TABLE 2. Parameters of coils.**

Parameters	Parameters of coils	
	Transmitter	Receiver
Number of turns	5	5
Diameter of wire	1.5 mm	1.5 mm
Wire pitch	2.05 mm	2.05 mm
Inductance	1.88 $\mu$ H	1.00 $\mu$ H
Inner diameter of coil	20 mm	10 mm
External diameter of coil	60 mm	40 mm

Table 3. The parameter of coupling structure for underwater inductive wireless power transfer system is shown as Table 4.

In the simulation work, the resonant frequency is set 200 kHz and the distance between the transmitter and receiver is set 20-100 mm. The simulation results are shown as Fig.6 to Fig.10.

When the metal plates placed inside the coupled structure for underwater wireless power transfer system, the simulated results are shown in Fig.8. The simulated results show that the power transfer will be prevented with the meatal plates. The electromagnetic fields will be exhibited. As a result, the power could not be delivered from the transmitter side to the receiver side. However, as shown in Fig.8, when the metal plates are placed outside the coupled structure, compared with the copper metal plates and the aluminum metal plates, the electromagnetic fields will be strongly enhanced with the iron meatal rectangle plates. What's more, the leakage magnetic fields could be reduced with the metal plates. As a result, the EMI noises will be decreased.

The curved metal plates are injected inside the coupled structure and outside of the coupled structure, respectively.



TABLE 3. Parameters of coils.

Metal Plate	Placement model	Inductance of Transmitter	Inductance of Receiver	Mutual Inductance
Without metal plates		1.88 $\mu\text{H}$	1.00 $\mu\text{H}$	119.74 $\mu\text{H}$
Iron	Model 1	2.54 $\mu\text{H}$	1.22 $\mu\text{H}$	9.10 $\mu\text{H}$
	Model 2	2.63 $\mu\text{H}$	1.29 $\mu\text{H}$	261.14 $\mu\text{H}$
	Model 3	2.42 $\mu\text{H}$	1.28 $\mu\text{H}$	6.85 $\mu\text{H}$
	Model 4	2.47 $\mu\text{H}$	1.28 $\mu\text{H}$	241.42 $\mu\text{H}$
Copper	Model 1	1.007 $\mu\text{H}$	685.42 $\mu\text{H}$	24.25 $\mu\text{H}$
	Model 2	1.08 $\mu\text{H}$	763.97 $\mu\text{H}$	323.192 $\mu\text{H}$
	Model 3	1.23 $\mu\text{H}$	704.97 $\mu\text{H}$	36.03 $\mu\text{H}$
Aluminum	Model 4	1.13 $\mu\text{H}$	750.8 $\mu\text{H}$	698.19 $\mu\text{H}$
	Model 1	1.01 $\mu\text{H}$	683.24 $\mu\text{H}$	23.45 $\mu\text{H}$
	Model 2	1.07 $\mu\text{H}$	761.45 $\mu\text{H}$	321.45 $\mu\text{H}$
	Model 3	1.21 $\mu\text{H}$	699.14 $\mu\text{H}$	36.10 $\mu\text{H}$
	Model 4	1.098 $\mu\text{H}$	750.32 $\mu\text{H}$	697.9 $\mu\text{H}$

TABLE 4. Parameters of coils with variable distance.

	1 mm	3mm	5mm	7mm
Inductance of Transmitter	3.02 $\mu\text{H}$	2.71 $\mu\text{H}$	2.54 $\mu\text{H}$	2.32 $\mu\text{H}$
Inductance of Receiver	1.57 $\mu\text{H}$	1.39 $\mu\text{H}$	1.22 $\mu\text{H}$	1.17 $\mu\text{H}$
Mutual Inductance	6.39 $\mu\text{H}$	7.63 $\mu\text{H}$	9.10 $\mu\text{H}$	11.38 $\mu\text{H}$

The simulated results are shown in Fig.8. When the curved metal plates are placed outside of the coupled structure, the electromagnetic will be highly enhanced, and the EMI noise will be restricted in the coupled structure area. When the curved metal plates placed inside the coupled structure, the power transfer will be prevented directly.

**A. UNDERWATER INDUCTIVE WIRELESS POWER TRANSFER SYSTEM**

When the inductive wireless power transfer system works in the marine environment, the eddy current loss will be generated. The eddy current loss is surveyed with the simulation. It can be seen in Fig.9. The eddy current loss of the inductive wireless power transfer system is tested with the four placement models. When the metal plates are placed outside of the coupled structure, the highest eddy current loss is generated with the rectangle metal plates. What's more, with the same placement model, the copper metal plates will have the highest eddy current loss as shown in Fig.10.

**B. UNDERWATER CAPACITIVE WIRELESS POWER TRANSFER SYSTEM**

The impact of AUVs' hull for underwater capacitive wireless power transfer system is also surveyed in this paper. The

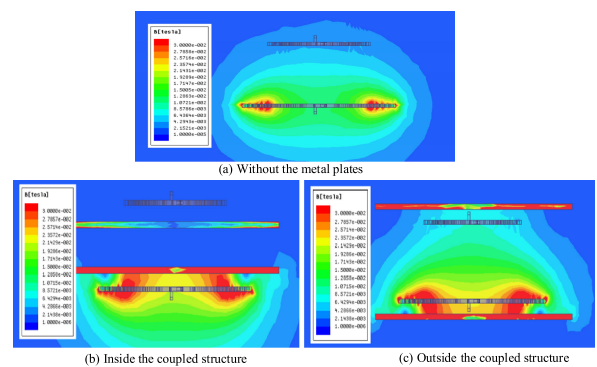


FIGURE 6. The impact of placement conditions of IPT system.

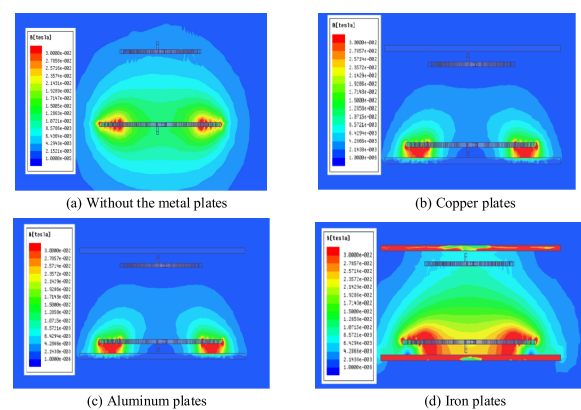


FIGURE 7. The impact of metal plates of model 1.

simulated results are shown in Fig.11. It can be seen from Fig.11 that the electric fields will be affected by the metal plates. When the metal plates placed inside the capacitive coupling structure, the strength of electric fields will be reduced. However, the electric fields will not disappear. As a

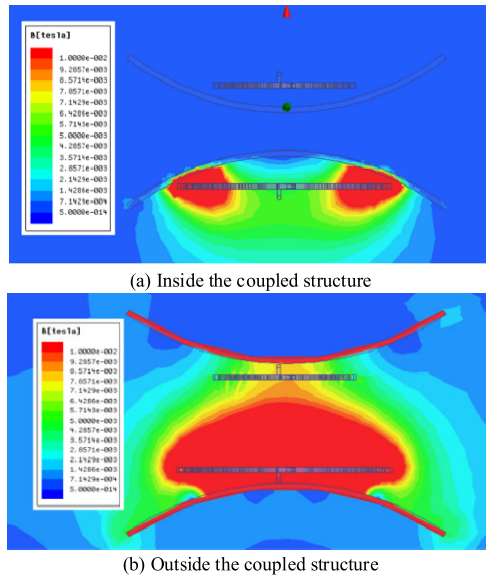


FIGURE 8. The impact of curved metal plates of IPT system.

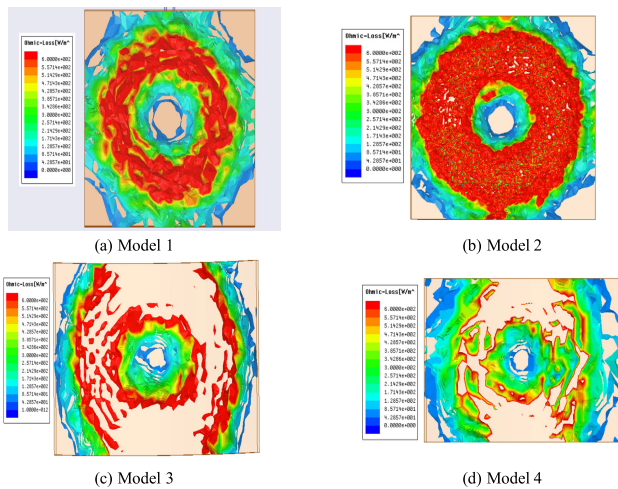


FIGURE 9. The impact of metal plates on eddy current loss of IPT system.

result, the power could still be transferred from the primary side to the secondary side based on high frequency alternating electric fields of underwater capacitive wireless power transfer system. This is the unique advantage of capacitive wireless power transfer system for underwater wireless charging for AUVs. On the other hand, the Fig.11 shows that, when the metal plates are placed outside of the capacitive coupled structure, the electric fields will be highly improved with the high-power transfer capacity under the conductive water environment.

C. EXPERIMENTAL VERIFICATION

The experiments are conducted to verify the theory analysis. The experimental setup is built as shown in Fig.12. For the underwater inductive wireless power transfer system, the rectangle metal plates, and the curved metal plates are respectively used to build the capacitive coupled structure

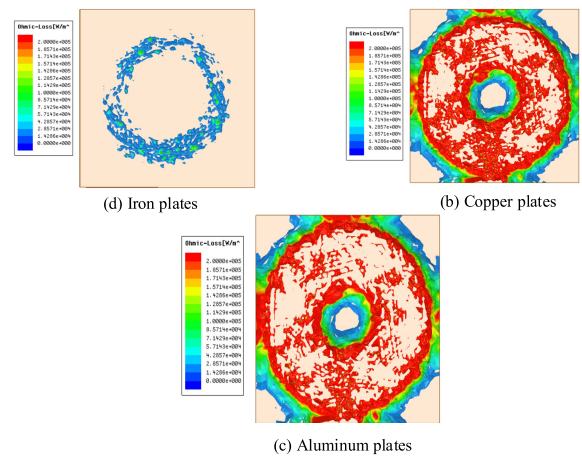


FIGURE 10. The impact of metal plates on eddy current loss of IPT system.

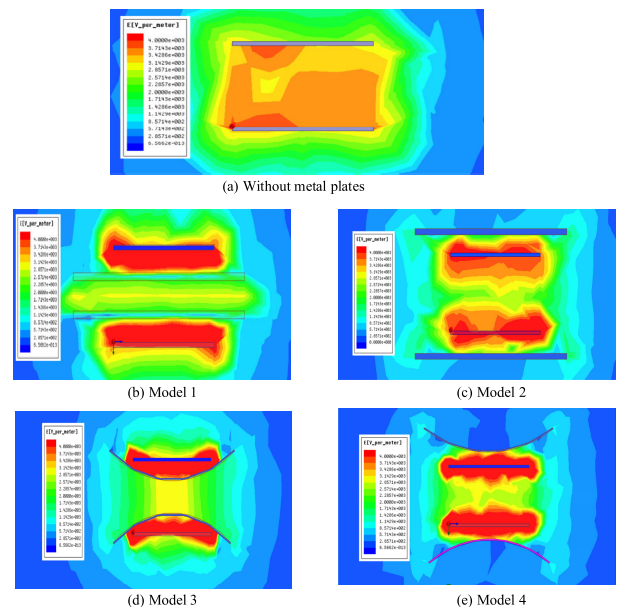
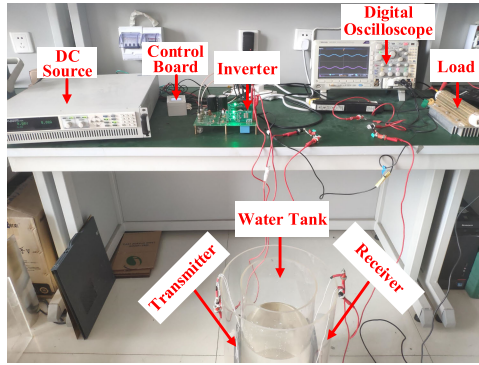


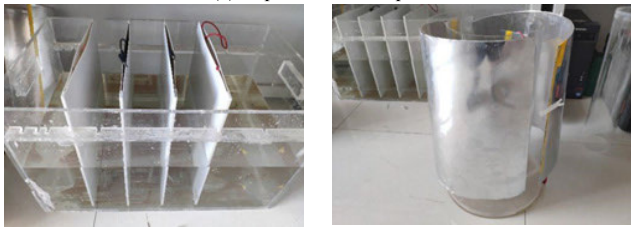
FIGURE 11. The impact of metal plates on electric fields for capacitive wireless power transfer system of CPT system.

to generate the high frequency alternating electric fields. A water tank is used to conduct the experiments with the 35%salinity water. The experimental results are shown as Fig13 and Fig.14. With the IPT method, when the metal plates are injected inside the coupled structure, the power transfer will be exhibited. What's more, when the metal plates are placed outside the coupled structure, the power transfer of the underwater wireless power transfer system will be not affected by the metal plates. As a result, the experimental results match the theory analysis and the simulation results very well.

It could be derived from the experimental results that the power delivery capacity of UCWPT system is less affected than the UIWPT system in the marine environment. The power could be transferred stably with the UCWPT method



(a) Experimental setup



(b) Coupled structure

FIGURE 12. Experimental setup and the coupled structure.

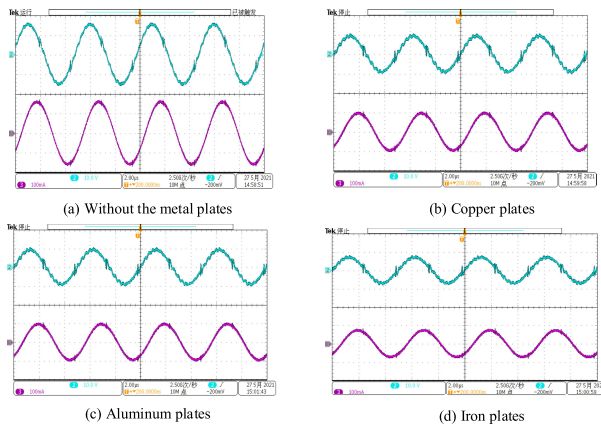


FIGURE 13. Experimental results for model 3 of CPT system.

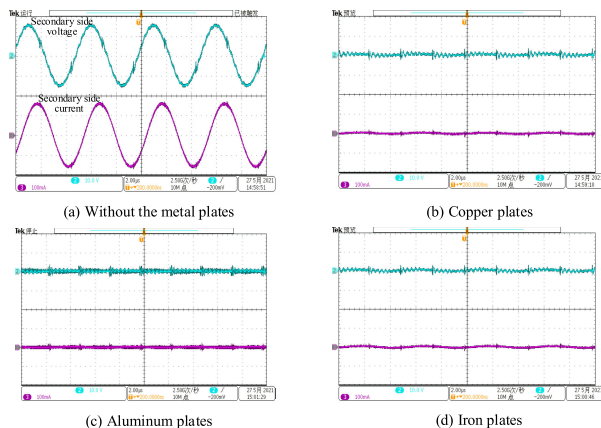


FIGURE 14. Experimental results for model 3 of the IPT system.

IV. CONCLUSION AND DISCUSSIONS

This paper presents a survey of the impact of AUVs’ hull for undersea wireless power transfer system on electromagnetic

fields, electric fields and the eddy current loss. The simulation and experiments are conducted to test the performance of coupled structure and the power transfer capacity. The simulated and experimental results show that the electromagnetic field and the electric field will be reduced when the metal plates placed inside the coupled structure. When the metal plates placed outside the coupled structure, the power transfer capacity of underwater wireless power transfer system will be enhanced. However, it also shows that, when the metal plates injected into the capacitive coupled structure, the power could still be transferred from the primary side to the secondary side with the low power level for the capacitive wireless power transfer system. The rectangle metal plate and the curved metal plate are all tested in this paper with the four placement models. The simulated data and the experimental data show that the shape of the metal plate has little effect on the power transfer of underwater wireless power transfer system and the capacity of power level.

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**LEI YANG** (Senior Member, IEEE) was born in Henan, China, in 1986. He received the B.S. degree in electric and information engineering from Information Engineering University, Zhengzhou, China, in 2011, and the M.S. degree in signal and information processing (SIP) and the Ph.D. degree in electrical engineering from Northwestern Polytechnical University, Xi'an, Shaanxi, China, in April 2014 and June 2017, respectively.

From September 2014 to September 2016, he had been studied as a Visiting Student at the University of California at Irvine, Irvine, CA, USA. He is currently working as an Assistant Professor at the Xi'an University of Technology. His research interests include nonlinear control methods, wireless power transfer systems, underwater communication, power delivery systems, switched-capacitor (SC) converter, dc-dc converter, the power source of electrical vehicles, and renewable energy integration.



**YUANQI ZHANG** was born in Shaanxi, China, in 1999. He is currently pursuing the master's degree in electrical engineering and automation with the Xi'an University of Technology. He is also a member of the Research and Development Team of an underwater wireless power transfer system at the Xi'an University of Technology. His main research interests include control strategy of the wireless power transmission systems and bidirectional dc-dc converter.



**XAOJIE LI** was born in Shaanxi, China, in 1998. She received the B.S. degree in electrical engineering and automation from the Xi'an University of Technology, Xi'an, Shaanxi, where she is currently pursuing the M.S. degree. She is also a member of the Research and Development Team of an Underwater Wireless Power Transfer System, Xi'an University of Technology. Her research interests include the control strategy of the wireless power transfer systems, nonlinear control methods, and bidirectional dc-dc converter.

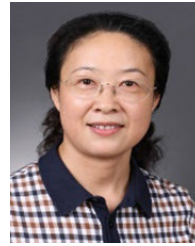


**BAOXIANG FENG** was born in Shaanxi, China. He is currently pursuing the M.S. degree in electrical engineering and automation with the Xi'an University of Technology. He is also a member of the Research and Development Team of Underwater Wireless Power Transfer System, Xi'an University of Technology. His research interests include the circuit design, wireless power transfer systems, switched-capacitor converter, and nonlinear control method.

**XINZE CHEN**, photograph and biography not available at the time of publication.



**JINGJING HUANG** (Member, IEEE) received the B.S. degree in electrical engineering from the Henan University of Science and Technology, Luoyang, China, in 2008, and the Ph.D. degree in electrical engineering from Xi'an Jiaotong University, Xi'an, China, in 2014. From April 2014 to November 2016, she was a full-time Lecturer with the Xi'an University of Technology, Xi'an. From 2016 to 2019, she was a full-time Postdoctoral Research Fellow with Nanyang Technological University, Singapore. She is currently an Associate Professor with the School of Electronic and Information Engineering, Xi'an Jiaotong University. Her research interests include renewable energy systems, high-frequency transformer, hybrid ac/dc microgrid, and high-power converters.



**AIMIN ZHANG** (Member, IEEE) received the B.Eng., M.Eng., and Ph.D. degrees from Xi'an Jiaotong University, Xi'an, China, in 1983, 1989, and 2008, respectively. Since 1983, she has been with the School of Electronic and Information Engineering, Xi'an Jiaotong University, where she is currently a Professor. Her current research interests include adaptive control, new energy control systems, and embedded intelligent measurement and control systems.

**TING YANG**, photograph and biography not available at the time of publication.



**DARUI ZHU** (Member, IEEE) received the B.S. degree in automation and the M.S. degree in detection technology and automatic equipment from Xi'an Polytechnic University, Xi'an, China, in 2007 and 2010, respectively, and the Ph.D. degree in electrical engineering from Xi'an Jiaotong University, Xi'an, in 2014. He is currently a Lecturer with the School of Electrical Engineering, Xi'an University of Technology. His research interests include modeling of nonlinear systems, complex network theory, and power system security analysis.



**XIANGQIAN TONG** (Member, IEEE) was born in Shaanxi, China, in 1961. He received the B.S. degree from the Shaanxi Institute of Technology, Hanzhong, China, in 1983, the M.S. degree from the Xi'an University of Technology, Xi'an, China, in 1989, and the Ph.D. degree in electrical engineering from Xi'an Jiaotong University, Xi'an, in 2006. He joined the Xi'an University of Technology, in 1989. Since 2002, he has been a Professor and the Academic Leader of Electrical Engineering at the Xi'an University of Technology. His research interests include the application of power electronics in power systems and control of power quality, especially the power filter, static synchronous compensator, and high-voltage direct current.

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