



**DESIGN IMPROVEMENTS OF A THAI SAIL WINDMILL  
FOR WATER PUMPING**

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**A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS  
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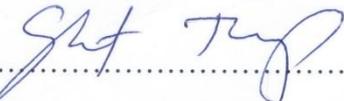
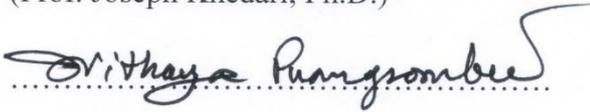
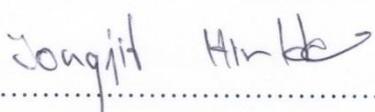
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### Abstract

This dissertation is focused on the design improvement and development of the Thai horizontal axis windmill intended for water pumping coupled to a water ladder pump and Archimedean's pipe-screw pump especially for low head high volume of open farm pond. Laboratory scales 1.0 meter diameter wind tunnel tests were conducted to assess the aerodynamic performance of Thai sail rotor model (TSRM) and the performance of characteristics of Archimedean's pipe-screw model (APSM). A family of Thai sail rotor model systems were manufactured with four, six, eight and twelve arms. The tests on Thai sail rotors are conducted in an open jet wind tunnel with a wind tunnel outlet opening of 1.2 meters in diameter. Experiments were carried out to optimize the different parameters like degree of solidity by varying the number and the size of the sails. The optimum power coefficient ( $C_p$ ) for the Thai sail rotor model is TSRM 12B-T0 of about 0.16 at trip speed ratio of 0.9. Archimedean's pipe-screw model testing were conducted to assess the performance of water pumping. A model of pump has been manufactured, 1.0 meter long with the blade small rubber tube was constructed. Experiments were carried out to optimize the different parameters by varying the pitch, rotation speed of the pump shaft, intake submergence, slope angle and the size of the blade. The optimized pitch of Archimedean's pipe-screw is 1.4D. These outputs were considered for the development the of prototype of the new generation of Thai sail windmill for water pumping to water ladder pump and Archimedean's pipe-screw pump. In the large scale, there were twelve triangular sails sweeping a circle of 8 meters diameter. In the construction of this windmill all efforts were made to maximize use of

materials and parts available in the local market. The construction cost of material and parts is 150,000 Baht excluding the cost of machining and fabrication. The result of performance tests of the prototype of Thai sail windmill coupled to water ladder pump have indicated a water pumping rate of 8.04 - 49.58 m<sup>3</sup>/hr at head of 1.0 meter under wind speeds of 1.5 - 4.5 m/s. It was found that the curves for the prototype of Thai sail windmill coupled to twelve Archimedean's pipe-screw pump of wind speed and the discharge of was increased depending on wind speed. The discharge amount varied between 9.56 – 38.23 m<sup>3</sup>/hr at head of 1.5 meters in wind speeds from 1.0 - 5.0 m/s.

**Keywords:** Sail windmill/ Wind power/ Water pumping/ Archimedean's screw pump/  
Wind pump

หัวข้อวิทยานิพนธ์	การออกแบบปรับปรุงกังหันลมแบบใบฟ้าของไทยเพื่อการสูบน้ำ
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สาขาวิชา	เทคโนโลยีและการจัดการพลังงานและสิ่งแวดล้อมอย่างยั่งยืน
วิทยาลัย	พลังงานและสิ่งแวดล้อมอย่างยั่งยืนรัตนโกสินทร์

#### บทคัดย่อ

วิทยานิพนธ์นี้มุ่งเน้นไปที่การปรับปรุง การออกแบบและพัฒนากังหันลมแบบใบฟ้าของไทย เพื่อการสูบน้ำต่อกับระหัดวิดน้ำและเครื่องสูบน้ำท่อเกลียวอะครีไมดิส โดยใช้สูบน้ำในบ่อน้ำ สระน้ำที่มีเขตก่ามีอัตราการสูบน้ำ สูง การทดสอบในห้องปฏิบัติการเพื่อหาประสิทธิภาพทางอากาศพลศาสตร์ ของแบบจำลองใบกังหันลมใบฟ้าของไทย (TSRM) โดยการทดสอบกับอุโมงค์ลมและหาประสิทธิภาพของแบบจำลองเครื่องสูบน้ำท่อเกลียว อะครีไมดิส (APSM) การทดสอบแบบจำลองกังหันลมใบฟ้าของไทยกับอุโมงค์ลมแบบเปิดขนาดเส้นผ่านศูนย์กลาง 1.2 เมตร โดยการสร้างแบบจำลองใบกังหันลมใบฟ้าของไทยขนาดเส้นผ่านศูนย์กลาง 1.0 เมตร แบบ 4 ใบ 6 ใบ 8 ใบและ 12 ใบ เพื่อหารูปแบบของแบบจำลองกังหันลมที่มีประสิทธิภาพสูงสุด โดยเปลี่ยนพารามิเตอร์ของใบกังหัน เช่น จำนวนใบและขนาดของใบกังหัน เป็นต้น ผลการทดสอบพบว่าแบบจำลองกังหันลมใบฟ้าแบบ TSRM 12B-T0 ให้ค่าสัมประสิทธิ์พลังงานสูงสุด ( $C_p$ ) ประมาณ 0.16 ที่อัตราความเร็วปลายใบกังหันเท่ากับ 0.9 การทดสอบแบบจำลองเครื่องสูบน้ำท่อเกลียวอะครีไมดิส โดยการสร้างเครื่องสูบน้ำที่มีความยาว 1.0 เมตร ใช้ท่อขนาดเล็กพันเกลียว เพื่อหารูปแบบของเครื่องสูบน้ำ ที่ให้สมรรถนะการสูบน้ำ ดีที่สุด โดยเปลี่ยนพารามิเตอร์ เช่น ระยะห่างของท่อเกลียว ความเร็วรอบ ระยะการจมน้ำ มุมเอียง และขนาดของท่อเกลียวของเครื่องสูบน้ำ ผลการทดสอบพบว่าแบบจำลอง ท่อเกลียวอะครีไมดิสที่มีระยะห่างของท่อเกลียวเท่ากับ 1.4D เป็นแบบที่ดีที่สุด ผลการทดสอบแบบจำลองดังกล่าวนำมาใช้สร้างต้นแบบกังหันลมแบบใบฟ้า รุ่นใหม่เพื่อ การสูบน้ำต่อกับระหัดวิด น้ำและเครื่อง สูบน้ำท่อเกลียว อะครีไมดิส ต้นแบบการสร้าง กังหันลมใบฟ้า ต้นแบบขนาดใหญ่ มีจำนวน ลิบสองใบ ใบเป็นรูปสามเหลี่ยม มีขนาดเส้นผ่านศูนย์กลาง 8 เมตร โดยใช้วัสดุและ อุปกรณ์ที่มีขายอยู่ทั่วไปในท้องตลาด ราคากังหันลมเพื่อการสูบน้ำโดยรวมประมาณ 150,000 บาท ผลการทดสอบ สมรรถนะของต้นแบบกังหันลม ใบฟ้าของไทย ต่อกับระหัดวิดน้ำ พบว่าอัตราการสูบน้ำของ ระหัดวิดน้ำที่เสด 1.0 เมตร เท่ากับ 8.04 - 49.58  $m^3/hr$  ที่ความเร็วลม 1.5 - 4.5  $m/s$  สำหรับผลการทดสอบ สมรรถนะของต้นแบบ กังหันลม ใบฟ้าของไทยต่อ

กับเครื่องสูบน้ำท่อเกลียวอะครีไมลแบบ 12 ท่อ พบว่าเมื่อความเร็วลมเพิ่มขึ้นอัตราการเครื่องสูบน้ำก็  
จะเพิ่มขึ้นมีอัตราการสูบน้ำที่เสด 1.5 เมตร อยู่ในช่วง 9.56 - 38.23 m<sup>3</sup>/hr ที่ความเร็วลม 1.0 - 5.0 m/s

**คำสำคัญ:** กังหันใบผ้า/ พลังงานลม/ การสูบน้ำ/ เครื่องสูบน้ำแบบอาร์คิเมดีสศกร/ กังหันสูบน้ำ

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## NOMENCLATURES

### Abbreviation explanation

1,...,12-APS	=	One,..., Twelve-Archimedean's pipe-screw
APS	=	Archimedean's pipe-screw
APSM	=	Archimedean's pipe-screw model
NRCT	=	National Research Council of Thailand
DEDP	=	Department of Energy Development and Promotion
NRCT	=	National Research Council of Thailand
TSR	=	Tip speed ratio
TSRM	=	Thai sail rotor model
TSRM 4B-T1,...,T5	=	Four blades of Thai sail rotor model-Type 1,...,Type 5
TSRM 6B-T0,...,T5	=	Six blades of Thai sail rotor model-Type 0,...,Type 5
TSRM 8B-T1,...,T3	=	Eight blades of Thai sail rotor model-Type 1,...,Type 3
TSRM 12B-T0,...,T2	=	Twelve blades of Thai sail rotor model-Type 0,...,Type 0

### Symbol

		<b>Unit</b>
$\omega$	rotational speed of the rotor	rad./s
$\lambda$	Tip speed ratio	-
$\sigma$	Rotor solidity	-
$\rho$	Density of material, air density	$\text{kg/m}^3$
$g$	Gravitational constant	$\text{m/s}^2$
$u$	Speed of rotor tip	m/s
$A$	projected area of rotor	$\text{m}^2$
$C_p$	The power coefficients	-
$C_q$	The torque coefficient	-
$H_a$	Vertical height	m
$P_{hyd}$	Hydraulic power	W
$P_s$	shaft power output	W
$P_w$	Wind power	W
$Q$	Discharge or Flow rate	$\text{m}^3/\text{s}$
$R$	Radius of rotor	m
$T$	brake frictional torque	N·m
$V$	Wind speed	m/s



# CHAPTER 1 INTRODUCTION

## 1.1 Background

Windmills have been in use for many centuries for pumping water, United Nations Economic and Social Commission for Asia and the Pacific. Major, S. et al [1] produced a wind map for Thailand, which combines and updates the wind speed data previously available. Thailand experiences generally very low wind speeds with typically average speed of not above 3 m/s. According to a report on wind resource assessment of Thailand done by the Department of Energy Development and Promotion (DEDP) in 2001, the fair wind areas in the Class 1.3 to Class 2 category (4.4 m/s wind speed at 50 m height) or higher are located on the west side of the Gulf of Thailand as shown in Figure 1.1 [2]. There are three basic types of windmill in active use for water pumping in Thailand; the slow speed sail rotor type, the high speed wooden rotor type and the multi-blade steel rotor type [3].

For at least 60 years, locally constructed windmills have been used for salt farming. The Thai bamboo mat windmills or a Thai sail windmill that is a type of slow wind speed turbine [4], are widely in use in Thailand in the region near Samut Sakorn and Samut Songkram as shown in Figure 1.2. A large number were made with sail rotor diameter varying between 7 to 9 meters. These windmills are actually constructed from wood, bamboo and cloth materials which often carry six triangular sails as shown in Figure 3. Power is transmitted by a chain coupled to a ladder pump. The operating data, starting wind velocity is 1.7 m/s, average discharge is 17.3 litres/sec at pumping head 0.6 m and average wind speed 17 km/h [4]. The commercial Thai sail windmill are suitable for water pumping in salt farm which fixed in azimuth, rotating one way in the southwest monsoon and reversing direction in the northeast monsoon [4],[5].

Cretan windmills is a type of sail windmill such as Thai sail windmill, used for grinding corn in the Greek island, used for pumping water for on Great. The Cretan-type windmill is particularly effective for low-speed winds ( $< 5\text{m/s}$ ) [6]. The characteristics of sail mill, observations were of brake load and speed found that, for high starting torque but moderate power follow from the use of large loosely sheeted sail, for higher power can be achieved at a higher speed but at the expense of starting torque by the use of large sails on alternate arms, or by the use of small sails on all the arms [7].