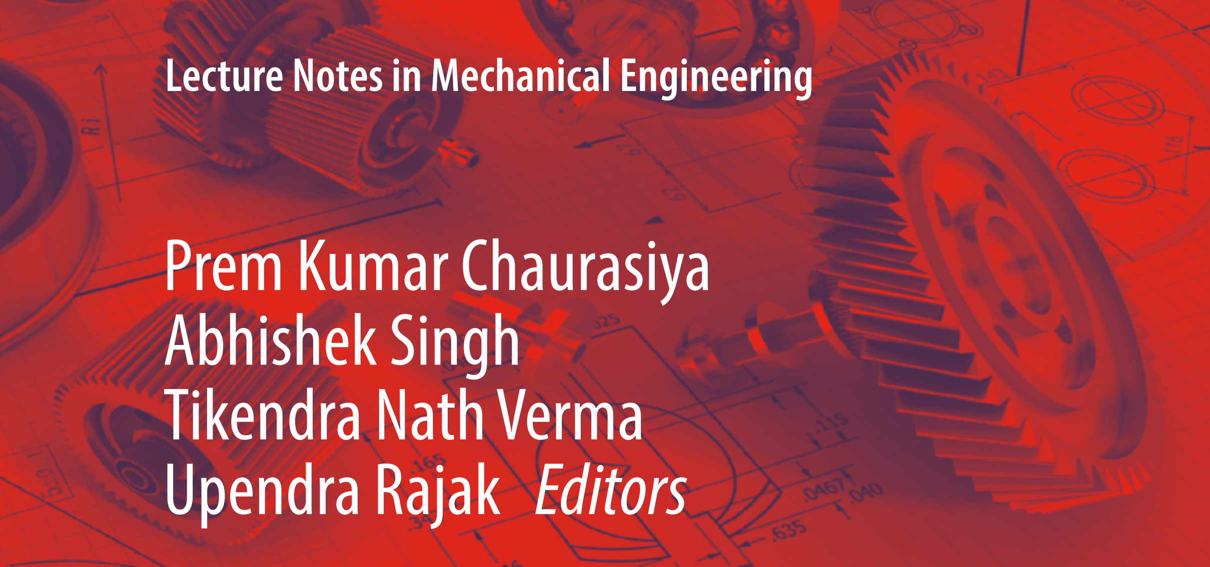

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Technology Innovation in Mechanical Engineering

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Editors

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Performance Enrichment of CI Engine Fueled with TiO_2 Additive Blended Biodiesel Through Air Nanobubbles

G. Senthilkumar, S. Lakshmi Sankar, and M. Purusothaman

Abstract The current work is intended at investigating the performance of bench scale standard DI-CI engine fueled with the blend of hone oil and TiO_2 nano-additive. Further, air nanobubbles (ANBs) are allowed to flow with fuel in the fuel pipe at 0.8% uniform volume rate. The performance enhancement is assessed by brake-specific fuel consumption (BSFC) and brake thermal efficiency (BTE), while the tail pipe emissions are examined by hydrocarbon (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) indices. The outcome of the study shows 11% diminution in BSFC, 3.1% improvement in BTE, and 14–19% decrement in tail pipe emissions.

Keywords Hone oil · Nano-additive · Air nanobubbles · Brake-specific fuel consumption · NO_x emission · CI engine

1 Introduction

Earth sustainability depends on the usage of fossil fuel sources for various day-to-day applications [1, 2]. So, researchers are focused on the efficacy of different engineering devices. CI engine is of such device employed in automobile sector whose efficacy needs to be enhanced through transforming its working fuel [3, 4]. Adding of nanoparticles in CI engine fuel is one such emerging field of research [5]. Hence, numerous investigators focused on mixing of nano-additives in biodiesels.

The rise in Al_2O_3 nanoparticle in fuel mixture caused an intensification in its flash point and heating value [6], while the same particles in base fuel released more CO_2 emissions [7, 8]. The combustion features of bio-fuel were enhanced with the zinc oxide additive [9]. The ANBs greatly influenced the performance of CI engine [10] due to their huge inner pressure. The attributes of ANBs in various liquid samples were investigated [11].

The exhaust through the manifold is the sole reason for low-level air contamination. They comprise gases which are hazardous to both humans and atmosphere.

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Hence, in this work, attention is focused on the diminution of emissions percentage. ANBs improve the thermo-physical properties of fuel through extended retaining and complete burning [12, 13]. The solidity of fuel was improved by adding ANBs in it, which further enhanced engine performance [14]. Blending of ANBs and hone biodiesel in turbulence accredited to the production of micro-dimensioned fuel bubbles [15, 16]. The objective of current assessment is to examine the behavior of CI engine fueled with hone oil and TiO_2 blends in the presence of ANBs.

2 Material, Equipment, and Test Procedure

2.1 Hone Biodiesel Preparation

Hone oil was produced by the technique of transesterification by employing high temperatures and homogeneous stirring. Finally, the attained mixture is thermally treated at 50 °C to separate glycerol from ester.

2.2 ANBs Production

ANBs produced through copper devices are injected in the leak-proofed fuel lines at 0.8% volume proportion. The dimension of ANBs utilized in the present assessment is in the order of 90–100 nm. Test fuel properties are indicated in Table 1.

Table 1 Thermo-physio characteristics of test fuels

Fuel blend / Property	B10	B20	B10 + ANBs	B20 + ANBs	B0	ASTM technique
Density (kgm^{-3}) at 22 °C	852	868	855	864	851	D4052
Kinematic viscidness (cSt) at 45 °C	0.15	0.18	0.143	0.171	0.286	D445
Lower heating value (MJ/kg)	37.4	35.9	40.6	38.5	45.7	D240
Flash point (°C)	109	107	104	102	64	D93
Cloud point (°C)	−6.4	−6.2	−6.4	−6.3	−41	D2500

Fig. 1 Experimental setup

2.3 Experimental Setup and Test Procedure

Prepared fuel mixtures were employed in bench scale standard CI engine test rig under various engine loads to evaluate its working characteristics. Before each experimentation, test rig is operated on B0 fuel for 10 min for the accuracy of data to be found at uniform engine speed of 1500 rpm. RTD instruments were utilized in assessing temperature and RH of intake air. All the tail pipe emissions were attained through FGA in real-time technique. The test Engine photograph and its technical details are shown in Fig. 1 and Table 2 correspondingly.

2.4 Error Analysis

The rate of fuel flow, torque, speed, and BSFC was found with measured errors of 0.3%, 0.3%, 0.2%, and 0.4% respectively, and 0.4% correspondingly. The data obtained through experiments were mean of values obtained for six repetitions.

Table 2 Apparatus technical details

Attributes	Range
Brand	Kirloskar
Cylinder count	1
Strokes per cyclic process	04
Chilling technique	Water cooling
Opening technique	Cold beginning
Ignition technique	CI
Cylinder dimension	8.75 * 11.0 cm
Indicated speed	1600 rpm
Indicated power	3.5 kW
Ergometer	Eddy current kind
CR	18.5:1

3 Outcomes and Discussion

3.1 Brake-Specific Fuel Consumption (BSFC)

Figure 2 depicts the BSFC variation with engine load for various fuel mixtures. From figure, it is identified that the company of ANBs in fuel lessens BSFC. The lowest

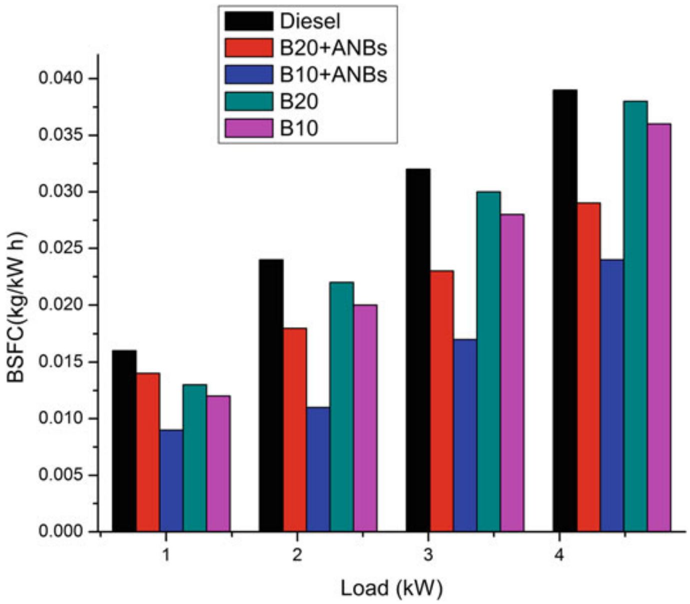

Fig. 2 Changes in BSFC with load

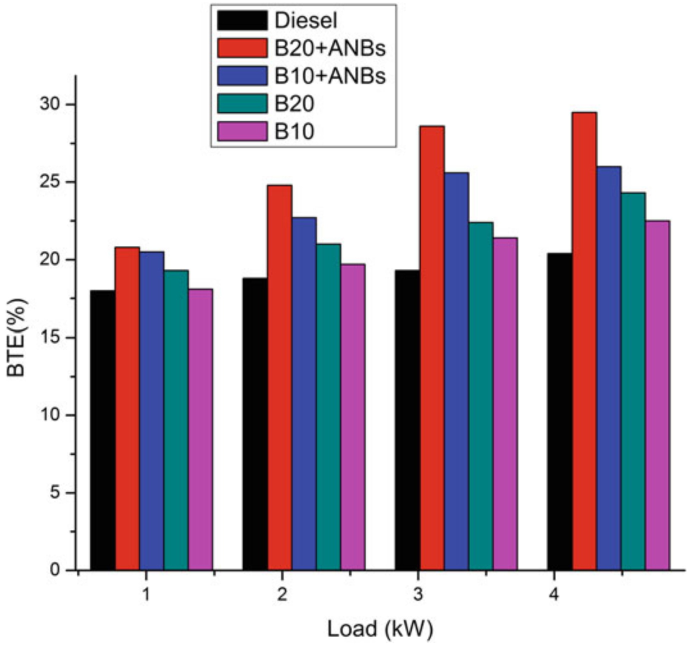

Fig. 3 BTE changes with load

BSFC is found for B10 and ANB pair. The reason for this can be accredited to the occurrence of rapid fuel air mixing in the CI engine during this blend.

3.2 Brake Thermal Efficiency (BTE)

Figure 3 demonstrates the BTE change with engine load for various fuel blends. From figure, it is identified that the presence of ANBs in fuel enhances BTE. The highest BTE is found for B20 and ANB pair. The motive for this can be attributed to the occurrence of complete burning of fuel in the CI engine during this blend.

3.3 Hydrocarbon (HC) Exhaust

Figure 4 demonstrates the HC emissions variation with engine load for various fuel blends. From figure, it is identified that the presence of ANBs in fuel diminishes HC exhaust. The lowest HC emission is identified for B20 and ANB pair. The reason for this can be attributed to the enhanced flame speed in the CI engine during this blend.

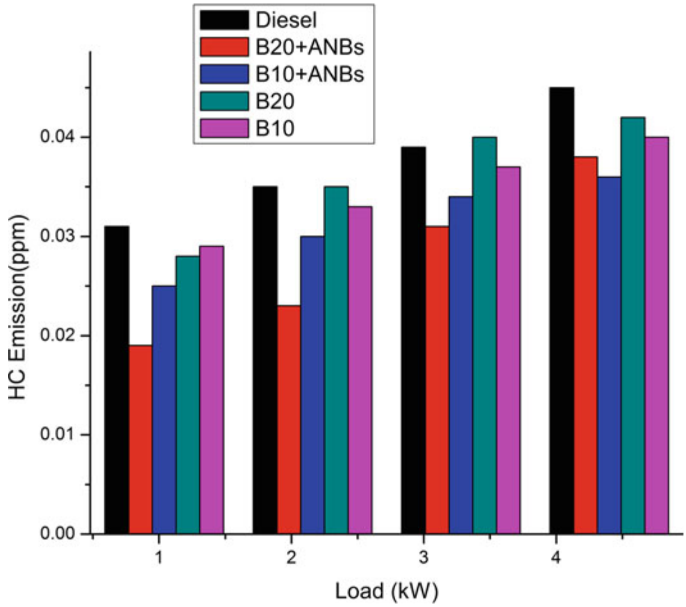

Fig. 4 Changes in HC emissions with load

3.4 CO Emission

Figure 5 depicts the CO emissions variation with engine load for various fuel blends. From figure, it is identified that the presence of ANBs in fuel diminishes CO exhaust. The lowest CO emission is identified for B10 and ANB pair. The reason for this can be attributed to the lowest enthalpy of the blend.

3.5 NO_x Emission

Figure 6 demonstrates the NO_x emissions variation with engine load for various fuel blends. From figure, it is identified that the presence of ANBs in fuel diminishes NO_x exhaust. The lowest NO_x emission is noticed for B10 and ANB combination. The reason for this can be accredited to the whole combustion of fuel mixture in the CI engine.

4 Conclusion

The subsequent inferences can be made from this study:

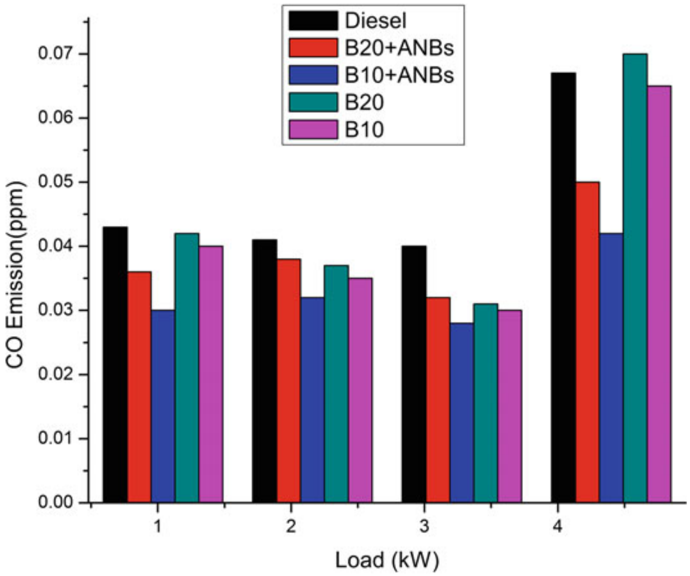

Fig. 5 CO emissions changes with load

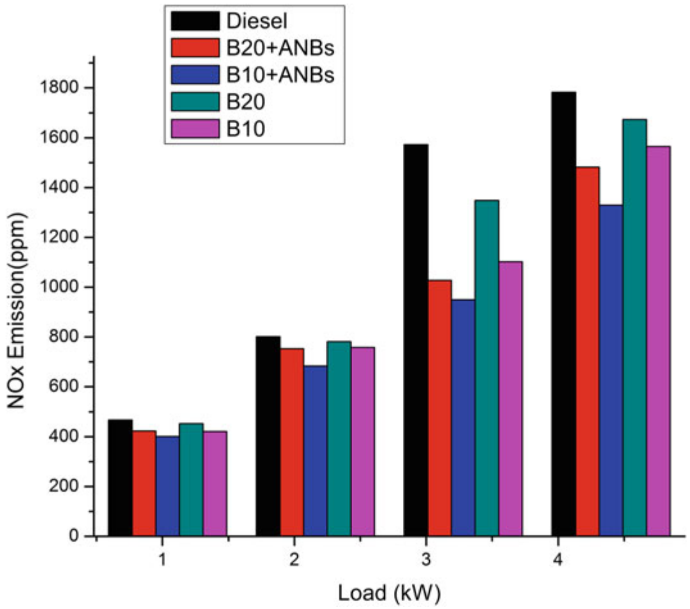

Fig. 6 Variation of CO emissions with load

1. ANBs in the fuel pipe line enhanced the performance attributes and emission characteristics of CI engine fueled with hone oil and TiO_2 additive.
2. Engine BSFC was reduced by 15% for B10 and ANB blend.
3. BTE of system was enhanced by 3.1% with B20 and ANB.
4. HC emissions was diminished by 15.1% with B20 and ANB.
5. CO and NO_x emissions were lessened by 19% and 14%, respectively, with B10 and ANB blend.

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Design and Optimization of NACA 0012, NACA 4412 and NACA 23,012 Aerofoils of Wind Turbine of Solar Updraft Tower Power Plant

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Abstract This work concentrates on the dimensional design and performance assessment characteristics of a wind turbine blade for a small-scale solar updraft tower power plant. Energy extraction from wind mainly relies on turbine blade design. Horizontal wind turbine blade with NACA 0012, NACA 4412 and NACA 23,012 profiles was designed and analysed by using a design method called blade element momentum (BEM) theory. This theory was applied to turbine blade to optimize various design factors like angle of attack (α), wind flow angle ($\emptyset$) and blade pitch angle (β), chord length of every sectional part of blade (c) and number of blades (N) and also to increase the smooth functioning of wind turbine and accordingly, increasing the power production. The power generation from wind turbine was also estimated for three different kinds of aerofoil blades (NACA0012, NACA4412 and NACA23012), and these are 0.59 W, 0.624 W and 0.61 W, respectively. The coefficients of lift and drag were estimated and analysed.

Keywords Solar updraft tower · Wind turbine · Blade element momentum theory · NACA 0012 · NACA 4412 · NACA 23012

1 Introduction

With a rapid depletion of fossil fuels and the raise in worldwide environment pollution, environment-friendly alternative energy sources (renewable energy sources) are the future. Among several types of alternative energy sources, solar and wind energy shares a large proportion. Nowadays, most of the energy utilisation in world is taken out from fossil fuel reserves and these energy resources come to an end in future. Then again this form of energy generation causes global warming, melting glaciers

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and environmental contamination. Therefore, it appears that the use of conceptually never-ending energy source which is solar power; necessary. Solar updraft tower (SUT) power plant is a novel method to generate electricity and has been increased in the past few decades. Construction and fabrication materials for such a power plants are comparatively economical and easily available which implies that they can be developed in any country [1].

According to the literature review, it is seen that a couple of reduced scale SUTs have been built up [2–9]. Few studies have been focused on numerical (CFD) studies of fluid flow behaviour inside the small-scale SUT power plant [10–13]. Some studies were focused on the airflow behaviour and also assessed several flow parameters like air pressure distribution and velocity [14, 15] at various locations inside the chimney (tower) and solar collector [14–16]. Air temperature, collector covers temperature and absorber plate temperature of the SUT setups were estimated through experiments [2, 3, 15, 17]. But no study has concentrated on the design of wind turbine blade of reduced scale SUT plants for the production of electricity. And, still no other study was carried out on evaluation of turbine blade angle optimization, number of blades and chord length distribution of turbine blade of SUT plant.

Hence, the essential goals of present research work are, (1) to build up a sophisticated design procedure and performance parameters evaluation of a wind turbine blade using BEM theory, (2) to optimize the various design parameters such as angle of attack (α), wind flow angle ($\emptyset$) and blade pitch angle (β), chord length (c) of each segment of blade and number of blades (N) under constant wind speed condition (3) to estimate the lift coefficient and drag coefficient to turbine blade, (4) to determine the power output of each aerofoil turbine blade and make a comparison.

2 Methodology

The purpose of this section is to design a wind turbine blade which operates underflow speed conditions (2–5 m/s). In the process of design of turbine blade, the first and foremost step is to obtain the best power performance by doing aerodynamic analysis of fit. The key parameters which influence the blade design include blade radius (R),number of blades (N), type of aerofoil, radial distribution of chord (c) and blade pitch angle (β).

A simple and an easy model introduced by Betz [18] can be utilized to find out the total energy extraction from a wind turbine. This theory can also helpful to estimate various aerodynamic forces like lift force, drag and axial thrust forces. This model can be used to see the impact of working of turbine blades on nearby wind field. This model purely operates on the law of conservation of linear momentum theory which developed 100 years before, in order to design and study the working of ship propellers. Rotational (or) wake flow is not considered for the analysis of Betz model [18].

2.1 Schmitz Model

Schmitz [18, 19] presented detailed and sophisticated model to investigate the realistic wind flow behaviour across the wind turbine by taking into consideration of wake flow (Fig. 1). Conservation of angular momentum theory and aerodynamic laws has been utilized to build up Schmitz model. In this model, the complete.

analysis of wind flow can be done by making it four divisions across the turbine. As shown in Fig. 1, the wind enters with an upstream velocity *V1*at the inlet to wind turbine (section-1). But the turbine blade goes through with relative velocity (*W)* in the rotor plane at Section 2 because of blade rotates with a velocity of *u.* The axial component ($V2$) of W acts perpendicular to the rotational plane of turbine. The wind speed is almost constant at exactly before and after the plane of rotation ($V2 = V3$). In Section 4, the wind velocity is far decreased *V4* due to most of the energy in the wind is extracted by turbine at rotor plane.

Figure 2 presents the wind and blade velocities and the corresponding angles at a specified distance, *r*, from the rotor axis. In order to design the rotor blade, the β, angle of attack (α), angle of relative wind to rotor plane (ϕ) and c of the blade should be defined. α is the angle of attack. β is blade twist angle. φ is wind flow angle. As per Fig. 3, it is observed that a little growth in the tangential velocity component due to rotational wind flow decreases $V2$. BEM theory helps stop redact the various aerodynamic forces (lift, drag, thrust and tangential) act on turbine blade elements

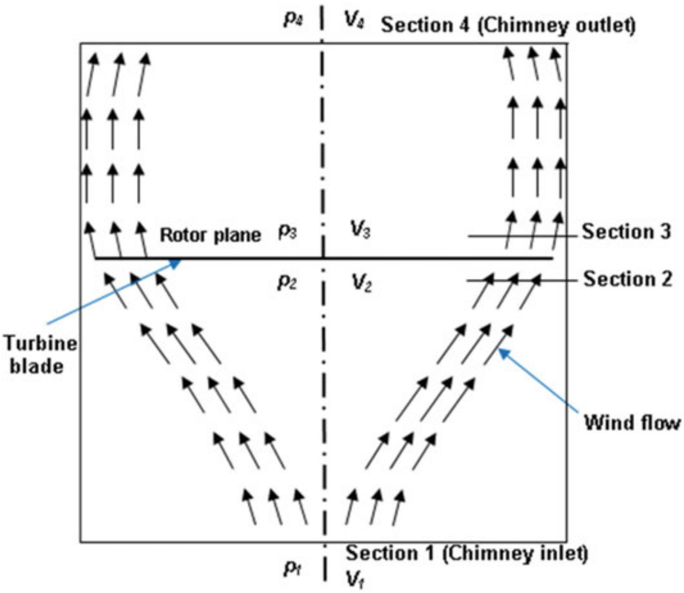

Fig. 1 Wind flow across the turbine

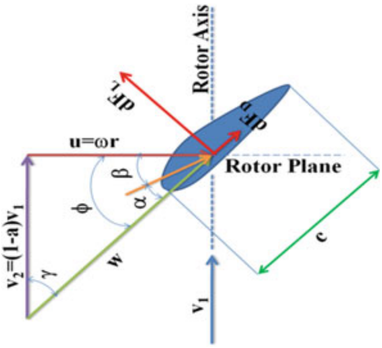

Fig. 2 Angles and velocities

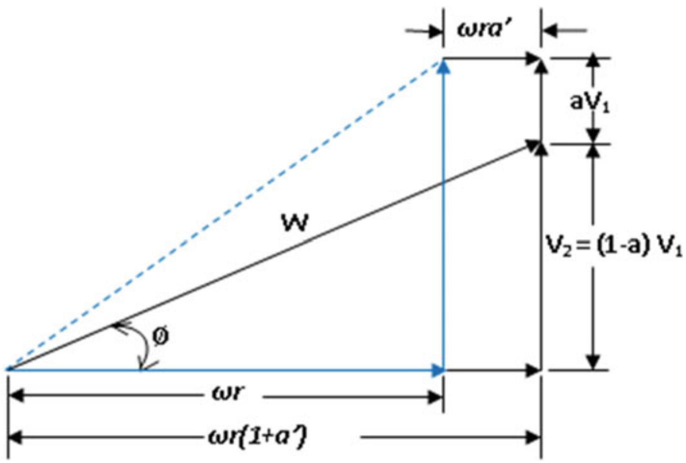

Fig. 3 Effect of wake flow at exit of turbine

and also to find out the optimum *a* and *a'* for achieving maximum energy extraction from air.

2.2 Blade Element Momentum (BEM) Theory

The primary goal of BEM theory is to maximize the lift force acts perpendicular to *W* on the blade and to minimize the drag force acts along the direction of wind on blade, which causes the force to act in rotational direction can be optimized.

Momentum theory: With the help of this theory, one can estimate the total tangential force which is developed by the blade in the plane of rotation.