Gazi Üniversitesi
Fen Bilimleri Dergisi
PART C: TASARIM VE TEKNOLOJİ

Gazi University
Journal of Science
PART C: DESIGN AND TECHNOLOGY

GU J Sci, Part C, 13(2): 641-652 (2025)

Aerodynamic analysis of wind turbine blades: A numerical study

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Article Info

Research article
Received: 10/04/2025
Revision: 12/05/2025
Accepted: 13/05/2025

Keywords

Wind turbine
Blade profile
Aerodynamics
Angle of attack
Performance

Makale Bilgisi

Araştırma makalesi
Başvuru: 10/04/2025
Düzeltme: 12/05/2025
Kabul: 13/05/2025

Anahtar Kelimeler

Rüzgar Türbini
Kanat profili
Aerodinamik
Hucüm açısı
Performansu

Graphical/Tabular Abstract (Grafik Özet)

In this study, the aerodynamic performances of different wind turbine blades including FX 63-137, NACA 6415, NACA 63-415 have been numerically investigated. XFLR5 has been employed to analyze the wind turbine blade at Reynolds numbers ranging from 1.5x10^5 to 1x10^6 and low angles of attack. / Bu çalışmada, FX 63-137, NACA 6415, NACA 63-415 dahil olmak üzere farklı rüzgar türbini kanatlarının aerodinamik performansları sayısal olarak incelenmiştir. XFLR5, 1.5x105 ila 1x106 arasında değişen Reynolds sayılarında ve düşük hücum açılarında rüzgar türbini kanadını analiz etmek için kullanılmıştır.

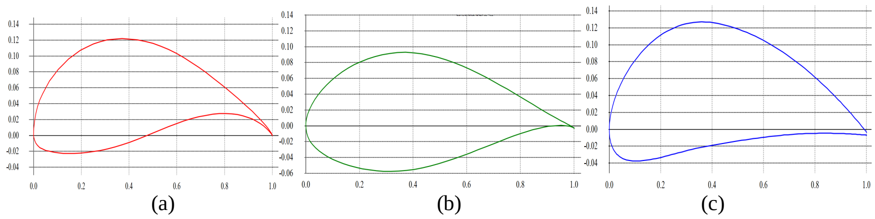

***Figure A**: Geometric views of the airfoils used in the study: a- FX 63-137, b- NACA 63-415, c- NACA 6415 / **Şekil A:** Çalışmada kullanılan kanat profillerinin geometrik görünümleri, a- FX 63-137 b- NACA 63-415, c- NACA 6415*

Highlights (Önemli noktalar)

- *The aerodynamic performance of wind turbine blades including FX 63-137, NACA 63-415, and NACA 6415 was carried out by using XFRL5 software at different Reynolds numbers and low angles of attacks. / FX 63-137, NACA 63-415 ve NACA 6415 içeren rüzgar türbini kanatlarının aerodinamik performansı, farklı Reynolds sayılarında ve düşük hücum açılarında XFRL5 yazılımı kullanılarak gerçekleştirilmiştir.*
- *Aerodynamic performances of three different airfoils were compared with each other. / Üç farklı kanat profillinin aerodinamik performansları birbirleriyle karşılaştırıldı.*
- *The wing airfoil with the best aerodynamic performance was determined. / En iyi aerodinamik performansa sahip kanat profili belirlendi.*

Aim (Amaç): *In this study, the best aerodynamic performance of three different wind airfoils was determined and compared with the studies in the literature. / Bu çalışmada, üç farklı rüzgar kanat profilinden en iyi aerodinamik performans gösteren profil belirlenmiş ve literatürdeki çalışmalarla karşılaştırılmıştır.*

Originality (Özgünlük): *The originality of the study is that the airfoils used in wind power plants are analyzed in numerical analysis and real wind data for a specific region is used. / Çalışmanın özgünlüğü, sayısal analizlerde rüzgar santrallerinde kullanılan kanat profillerinin incelenmesi ve belirli bir bölgeye ait gerçek rüzgar verisinin kullanılmasıdır.*

Results (Bulgular): *The best aerodynamic performance (the higher C_L/C_D ratio) was 109.14 with FX 63-137 blade profile at angle of attack 3 degree and 1x10^6 Re number. The maximum C_L/C_D ratio with the NACA 63-415 blade profile was 104.28 at 4 degree angle of attack, while that for the NACA6415 blade profile was is 102.11 at the 6 degree angle of attack and 1x10^6 Re number. / En iyi aerodinamik performans (daha yüksek CL/CD oranı) 3 derece hücum açısında ve 1x106 Re sayısında FX 63-137 kanat profili ile 109.14 olarak elde edilmiştir. NACA 63-415 kanat profili ile maksimum CL/CD oranı 4 derece hücum açısında 104.28 iken, NACA6415 kanat profili için bu oran 6 derece hücum açısında ve 1x106 Re sayısında 102.11'dir.*

Conclusion (Sonuç): *The aerodynamic efficiency of wind turbine blades is largely influenced by the shape of the blades. XFRL5 has been shown to be a fast and reliable tool for determining the aerodynamic performance of wind turbine airfoils. / Rüzgar türbini kanatlarının aerodinamik verimliliği büyük ölçüde kanatların şeklinden etkilendiği belirlenmiştir. XFRL5 yazılımının rüzgar türbin kanat profillerinin aerodinamik performansını belirlemek için hızlı ve güvenilir bir araç olduğu görülmüştür.*

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DOI: 10.29109/gujsc.1672741

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Abstract

In this study, the aerodynamic performances of different wind turbine blades including FX 63-137, NACA 6415, NACA 63-415 have been numerically investigated. XFLR5 has been employed to analyze the wind turbine blade at Reynolds numbers (Re) ranging from $1.5x10^5$ to $1x10^6$ and low angles of attack ($0^0 \leq \alpha \leq 20^0$). The lift ($C_L$), drag($C_D$), and pitch moment ($C_M$) coefficients, and C_L/C_D ratio of the wind turbine blades have been evaluated. Numerical lift coefficients obtained using XFLR5 and lift coefficients from the literature have beeen compared and it has been found that they have been compatible with each other. According to numerical analyzes, the highest C_L/C_D ratio, as called aerodynamic efficiency, was obtained as 109.14 with FX63-137 blade at Reynolds number (Re) of $1x10^6$, the lowest C_L/C_D ratio was obtained as 2.63 with NACA 63-415 blade. Also, the maximum C_L/C_D ratio with the NACA 63-415 blade profile was 104.28, while that for the NACA6415 blade profile was 102.11 at Re of $1x10^6$. The analysis results show that C_L/C_D ratio increases with the increase in the angle of attack up to the stall angle, and then begins to decrease in all studied blades.

Rüzgar Türbini Kanatlarının Aerodinamik Analizi: Sayısal Bir Çalışma

Makale Bilgisi

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Öz

Bu çalışmada, FX 63-137, NACA 6415, NACA 63-415 olmak üzere farklı rüzgar türbini kanatlarının aerodinamik performansı incelenmiştir. XFLR5, $1.5x10^5$ ile $1x10^6$ aralığındaki Re değerlerindeda ve düşük hücum açılarında ($0^0 \leq \alpha \leq 20^0$) rüzgâr türbini kanatlarının analizini yapmak için kullanılmıştır. Rüzgâr türbini kanatlarının taşıma kuvveti (C_L), sürükleme kuvveti (C_D) ve eğim momenti (C_M) katsayıları ve C_L/C_D oranı değerlendirilmiştir. XFLR5 kullanılarak elde edilen C_L ile literatürden elde edilen C_L değerleri karşılaştırılmış ve birbirleriyle uyumlu oldukları bulunmuştur. Sayısal analizlere göre, aerodinamik verimlilik olarak adlandırılan en yüksek C_L/C_D oranı, $1x10^6$ Re değeri için FX63-137 kanadında 109.14 olarak elde edilirken, en düşük kaldırma katsayısı-sürükleme katsayısı oranı 2.63 olarak NACA 63-415 kanadında elde edilmiştir. Ayrıca, NACA 63-415 kanat profili için maksimum C_L/C_D oranı 104.28 iken, NACA6415 kanat profili için bu oran 102.11 olmuştur. Analiz sonuçları, C_L/C_D oranının hücum açısının artmasıyla durma açısına kadar arttığını ve daha sonra incelenen tüm kanatlarda azalmaya başladığını göstermektedir.

1. INTRODUCTION (GİRİŞ)

Energy plays an important role in the economic, technological, and social development of modern societies. Especially electrical energy is indispensable in many areas, from healthcare to communication infrastructures, industry to transportation, as one of the basic elements of our daily life. The absence of electrical energy creates a situation that can profoundly affect not only individuals' daily lives but also global economic activities. Renewable energy sources offer an environmentally friendly alternative with almost zero carbon footprint compared to fossil fuels. Thanks to its geographical location and natural resources, Turkey has significant reserves in terms of renewable energy potential. As of March 2025, Turkey's total installed capacity has reached 118.185 MW, with wind energy contributing 13.236 MW of this capacity[1]. In line with the goals of reducing global warming, wind energy has been proposed as one of the main energy sources in international initiatives such as the Paris Climate Agreement prepared by the United Nations and the European Green Deal by the European Commission[2]. According to the sources, the forecasts of Türkiye's electrical energy production for the 2025-2035 period are given in Table 1[3]. When the table is examined, it is clearly seen that

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10.10% of electricity production is obtained from wind energy for 2025 year and it is the fourth highest source. A wind turbine is a device that converts the kinetic energy in the wind into electrical energy[4]. The kinetic energy of the wind causes the rotor to spin when it strikes the blades of the turbine, thereby generating mechanical energy. To benefit most efficiently from the wind potential of the selected geography in wind turbines, the aerodynamic design of the blades is one of the most critical factors. Also, the wind turbine blade's angle of attack is one of the most important design parameters for industrial wind turbines. Blade efficiency is directly related to the blade profile used. The aerodynamic performance of blade profiles is evaluated based on C_L, C_D, and C_L/C_D ratio. Additionally, as of the end of March 2025, the number of electricity generation plants in Turkiye has reached 35,160 (including unlicenced plants). The distribution of power plants by resources is as follows: 768 hydraulic, 72 coal, 376 wind, 66 geothermal, 333 natural gas, 33,086 solar and 459 other power plants.

When the relevant literature is examined, it is seen that much numerical and experimental research was conducted to determine the aerodynamic performance of airfoils. These are briefly given below. Guleren and Demir[5] carried out numerical analysis on six blade profiles with different geometries at high Reynolds numbers and low angles of attack ($0° \leq \alpha \leq 20°$). Among the examined blade profiles, considering the CL–α and CL/CD–α variation, it was found that the CLARK-Y blade profile had the best performance. Evran and Yildir[6] evaluated the lift and drag coefficient performance of NACA 0009 and NACA 4415 profiles under constant wind speed and various angles of attack using Ansys. As a result of this study, the NACA 4415 blade profile exhibited maximum lift and minimum drag coefficients compared to the NACA 0009 blade profile. It was observed that the increase in the angle of attack raised the lift and drag coefficients for both blade profiles. İnan and Kaplan[7] investigated the effect of lower surface geometry of the NACA 63-415 blade profile on the aerodynamic performance using Ansys. In the study, new blade profiles were obtained by reducing the dimensions of the lower surface by 10%, 20%, and 30%. Akın et al.[8] numerically examined the effect of the spar structure on aerodynamic performance in the NACA 2412 of wind turbine blad. The blade profiles were modeled using the Rhinoceros, and flow analysis was conducted with Ansys. They concluded the spar structure did not have a positive effect on aerodynamic performance at high angles of attack. Düz and Yıldız[9] have numerically investigated the performance of five wind blades at different angles of attack and different wind speeds. Guzelbey et al. [10] analyzed the aerodynamic performance of sailplanes with the help of XFLR5 under the same validated conditions for nine different airfoils. They found that the airfoils were equally to be the most efficient airfoils. Şahin and Acır [18] conducted numerical and experimental studies on NACA 0015 airfoil. They reported that the maximum efficiency was obtained at 80° angle of attack. They also observed that the numerical and experimental results are compatible with each other. Selig and Granahan [19] investigated the performance of different wind turbine airfoils including E387, S822, SD2030, FX63-137, S834 and SH3055 in a wind tunnel. Alaskari et al. [20] studied on the SG6043 airfoil used in wind turbines. They concluded that the maximum aerodynamic performance was observed at 2 degree angle of attack. Koç et al.[21] investigated the lift coefficient and lift-drag ratio of the SG6043 airfoil by using QBlade and Ansys at different angles of attack. They determined that the maximum C_L/C_D ratio was 1.22 and the angle of attack with maximum performance was 4.50 degree for the SG6043 airfoil. Parezanovic et al.[22] calculated the transport and drag coefficients using CFD and Xfoil to optimize three different wind turbine blades. They compared their numerical results with experimental results and found them to be in good agreement.

Condesidering the above literature survey, it is seen that there is much research on the aerodynamic performance of different wind turbine blades. To the best of the authors' knowledge, comparison of the aerodynamic performance of wind turbine airfoils including FX 63-137, NACA 63-415, and NACA 6415 using real wind measurement data has not been yet investigated at different Re numbers and low angles of attack for Bandırma, Turkiye. In this study, the aerodynamic performance of new types of wind turbine blades is examined using actual wind data of a certain region.

Table 1. Turkiye's electricity production forecast from different sources [3] (Türkiye'nin farklı kaynak elektrik üretim tahmini [3])

	Year		
Source	**2025 [TWh]**	**2030**	**2035**
Thermal	196.4	201.2	173.7
Nuclear	18.6	37.2	55.8
Hydroelectric	81.9	87.9	87.9
Wind	38.3	53.7	90.1
Solar	28.3	52.2	84.0
Other	16.7	20.5	16.2
Total	380.2	452.7	507.7

2. ANALYSIS OF WIND TURBINE BLADES USING XFRL5 (XFRL5 KULLANILARAK RÜZGÂR TÜRBİN KANATLARININ ANALİZİ)

Aerodynamic performance analysis of blades used in wind turbines can be performed by various methods. These include experimental methods such as wind tunnel tests, theoretical and empirical methods, techniques such as computational fluid dynamics (CFD) and regional momentum theory (BEM). In the present study, the aerodynamic performance analysis of wind turbine blades was performed by a method based on potential flow theory. XFLR5, which is widely preferred for aerodynamic calculations and design, was used in the analyses[11]. XFLR5 is an open source potential flow solver enhanced with various features and interfaces added to the XFOIL code developed by Mark Drela [13]. In this study, the aerodynamic performance parameters such as lift coefficient (C_L), drag coefficient (C_D), moment coefficient (C_M) and aerodynamic efficiency ratio (C_L/C_D) were investigated in detail. According to the obtained data, the performances of the blade profiles commonly used in wind turbines were evaluated comparatively. For the selection of the region, the wind potential in Bandırma, Türkiye was evaluated and it was decided to carry out the study in the Bandırma region. The average wind speed measured at 80 m height in the Bandırma region was determined as 7.6 m/s [13]. As a result of the literature review, analyses were performed on three different wing turbine blades including NACA 63-415, NACA 6415 and FX 63-137, which were determined to have high aerodynamic performance. While the NACA series offers classical designs optimized for laminar flow, the FX 63-137 is a modern and efficient blade. All three blades selected in the study are widely used in today's wind turbines.

Reynolds number is defined by the ratio of inertial forces to that of viscous forces as stated in equation (1). This dimensionless number is used to determine the type of flow pattern as laminar or turbulent.

Re number for airfoil is defined as

$$\mathrm{Re} = \frac{\rho V c}{\mu} \tag{1}$$

where ρ is the fluid density, V is the flow velocity, c is the cord length of airfoil, and μ is dynamic viscosity of the fluid.

The lift and drag forces acting on the wind turbine blade and pitching moment are given below:

$$\mathrm{L} = \frac{1}{2}\mathrm{C_L}\rho \mathrm{A}\mathrm{V}^2 \tag{2}$$

$$\mathrm{D} = \frac{1}{2}\mathrm{C_D}\rho \mathrm{A}\mathrm{V}^2 \tag{3}$$

$$\mathrm{M} = \frac{1}{2}C_{\mathrm{m}}\rho \mathrm{c}\mathrm{A}\mathrm{V}^2 \tag{4}$$

where L is the lift force, D is the drag force, M is the pitching moment, ρ is the fluid density, A is the reference area, V is the velocity, c is the chord-length and C_L, C_D, and C_{m} are the lift, drag, and pitching moment coefficients, respectively. The geometric properties of the airfoils selected for the study are given in Table 2.

In the present study, three different non-symmetrical airfoil geometries were taken from Ref [14]. These geometries are given in Figure 1a-c.

Table 2. Geometric properties of the blades used in study[14] (Çalışmada kullanılan kanatların geometrik özellikleri[14])

Blade profile	M (Serial Number)	P (distance from minimum pressure zone)	t (thickness)
FX63-137	63	30%	13.5%
NACA 63-415	6	30%	15%
NACA 6415	6	40%	15%

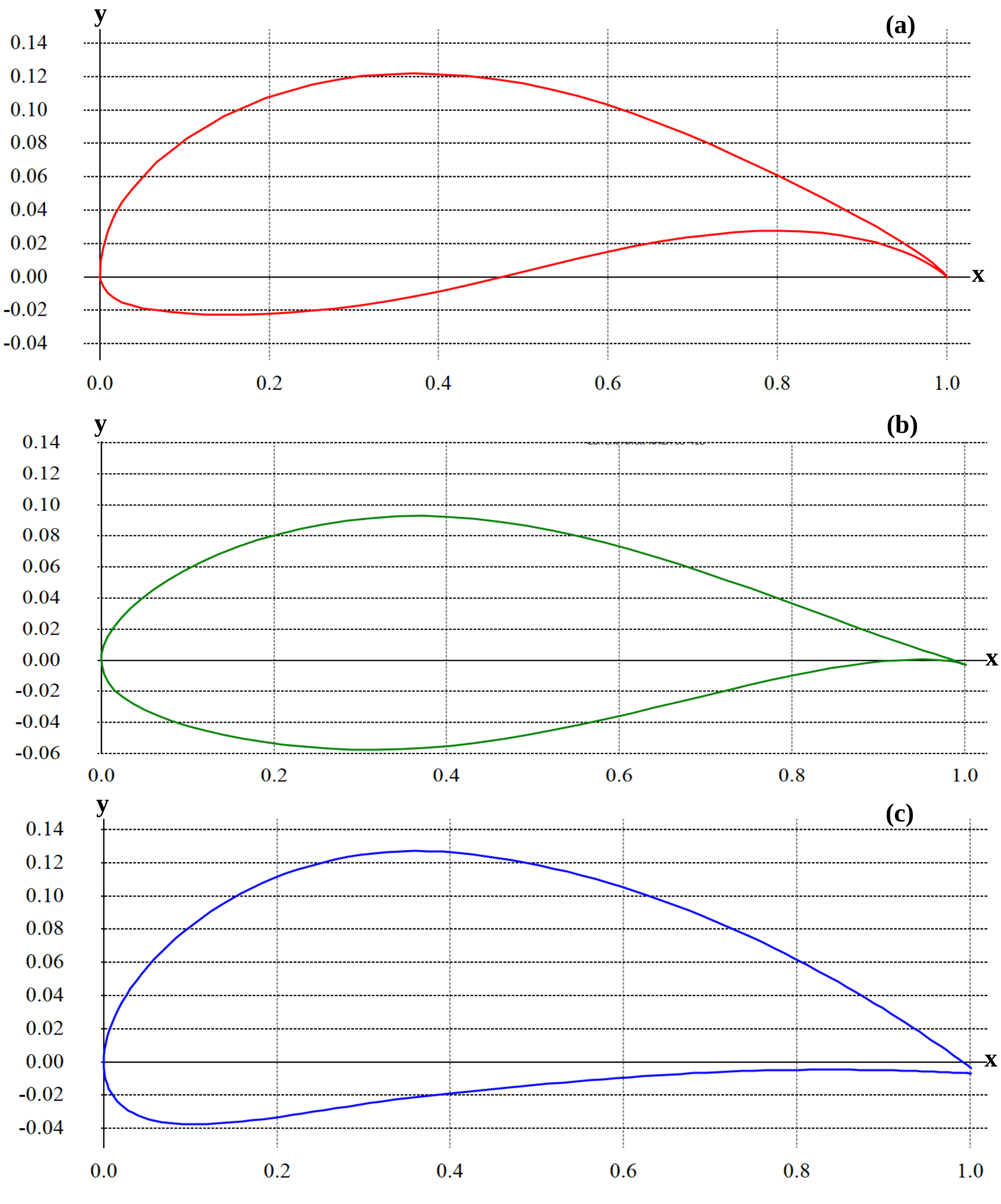


Figure 1. Geometric views of the airfoils used in the study: a- FX 63-137, b- NACA 63-415, c- NACA 6415 (Çalışmada kullanılan kanat profillerinin geometrik görünümleri, a- FX 63-137 b- NACA 63-415, c- NACA 6415)

From literature research, it was determined that Bandirma, Türkiye was suitable for this study. High wind potentials were discovered in different regions in Balıkesir, Türkiye. However, the wind data to be used in this study will be taken from the Bandırma, Türkiye. The wind properties for Bandirma region at 80 m are given in Table 3.

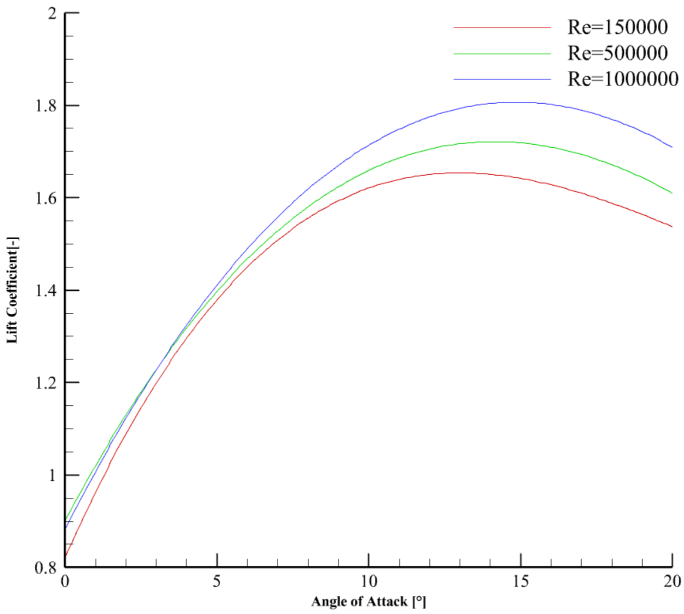
The numerical analyses were performed by comparing the aerodynamic performances of these wind turbine blades defined in the XFLR5. In the analyses, the performances of the blade profiles for the ranges of changes in angles of attack from 0 to 20 degrees and using three different Re numbers including 1×10^5, 5×10^5, and 1×10^6 were examined.

Table 3. Wind speeds (m/s) at 50m and 80m altitude for Bandırma, Türkiye [9] (Türkiye /Bandırma 50 m ve 80 m irtifadeki rüzgar hızları[9] (m/s))

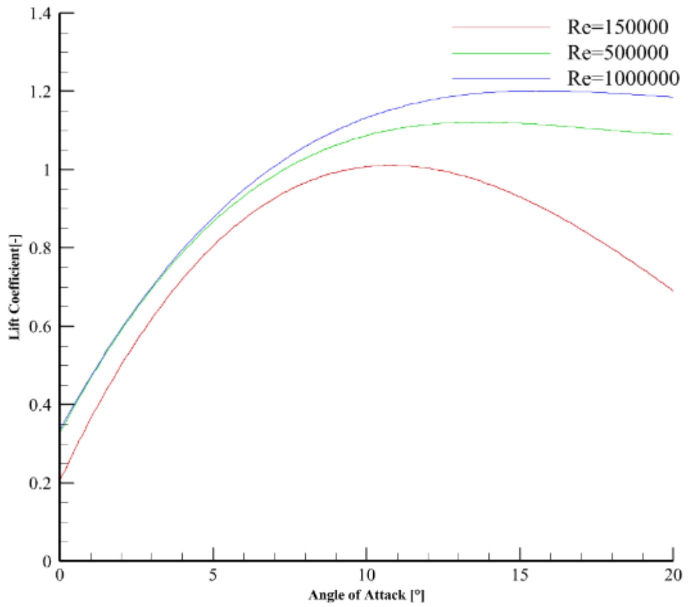
Altitude [m]	Highest wind speed [m/s]	Lowest wind speed [m/s]	Average wind speed [m/s]
50	8.19	5.32	6.61
80	9.89	6.17	7.6

3. RESULTS AND DISCUSSION (SONUÇLAR VE TARTIŞMA)

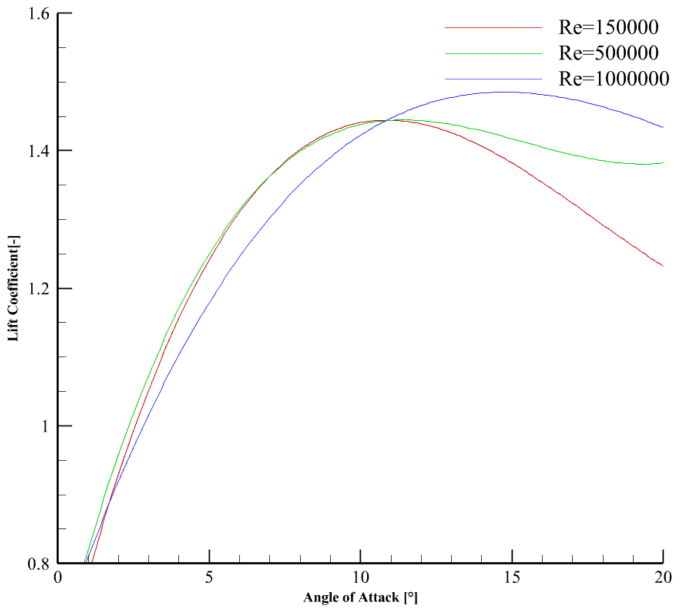
In this study, aerodynamics performance of three different wind blade profiles including FX 63-137, NACA 6415 and NACA 63-415 was comparatively analyzed using XFLR5 at a speed of 7.6 m/s and angles of attack between 0° and 20°. Within the scope of the analyses, lift coefficient (C_L), drag coefficient (C_D), lift coefficient/drag coefficient ratio (C_L/C_D) and pitching moment coefficient (C_m) values of each blade airfoil were investigated at different angles of attack ($0^0 \leq \alpha \leq 20^0$) and different Re numbers. These parameters were compared with each other in detail. Lift coefficients of the blade profiles vs angles of attack of airfoils are given in Figure 2a-c. As seen from this figure, all three airfoils exhibited stall behavior in the range of approximately 16-17 degree angle of attack. This situation reveals that the examined airfoils exhibit similar properties in terms of stall characteristic. The FX 63-137 profile stands out as the profile with the highest lift coefficient among the three airfoils studied, reaching a C_L of 1.80 just before the stall point in the attack angle range between 0° and 20°. NACA 6415 and NACA 63-415 profiles exhibit a similar trend and lower lift coefficient. At all blade profiles, lift coefficient increases with increasing of Re number and increase with the increasing of the angle of attack up to the stall angle, and then begins to decrease. This phenomenon is known as stall in flows over airfoils and at sufficiently large angles of attack the boundary layer is no longer adhering to the surface and separates from it.



(a)



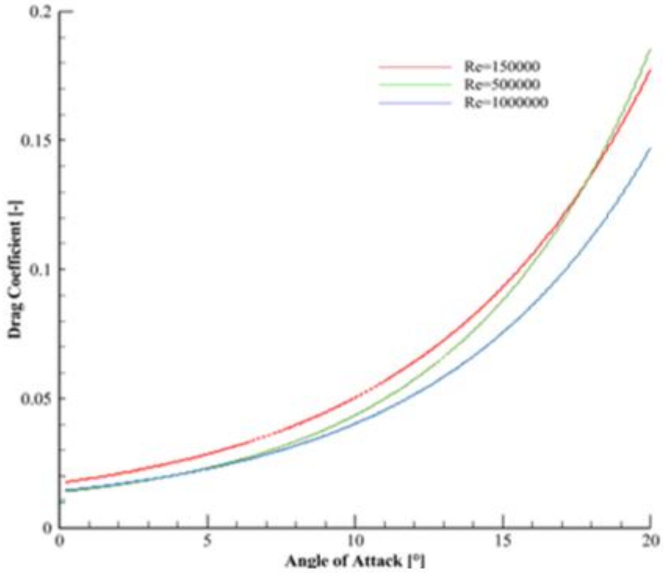
(b)



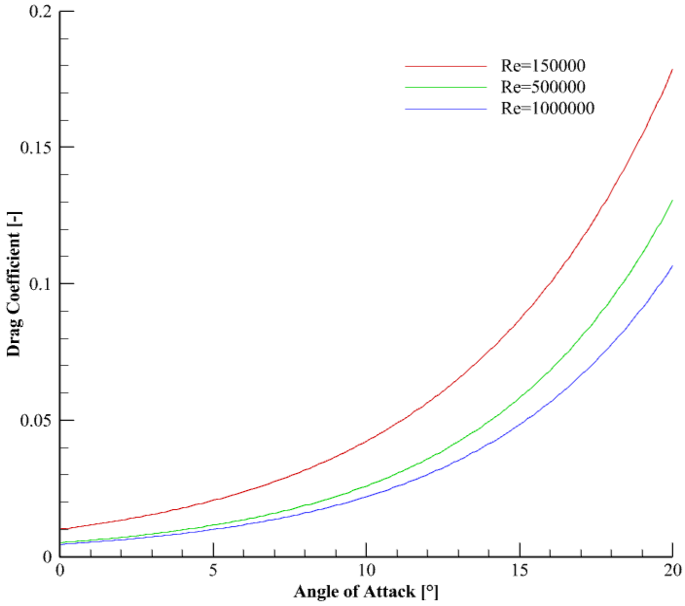
(c)

Figure 2. Change of the lift coefficient (C_L) of the blade profile with the angle of attack at different Re numbers: a- FX 63-137, b- NACA 63-415, c- NACA 6415 (Kanat profilinin taşıma katsayısının (C_L) farklı Re sayılarında hücum açısı ile değişimi: a- FX 63-137, b- NACA 63-415, c- NACA)

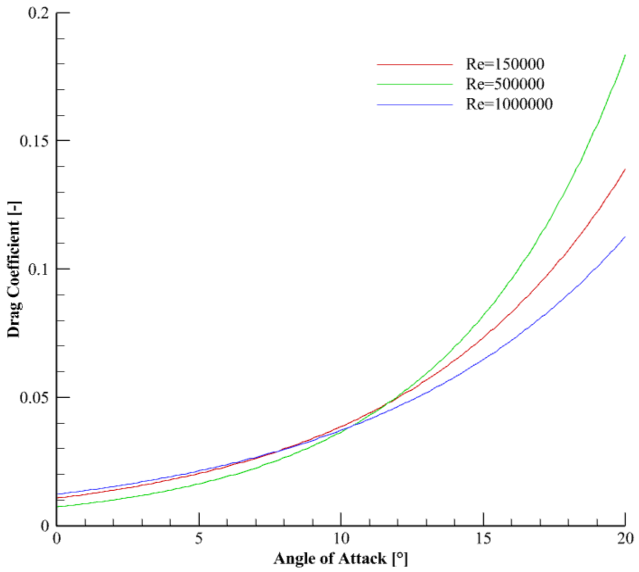
Variation of drag coefficient, C_D, with angle of attack is depicted in Figure 3a-c at different Re numbers. As it can be clearly seen in Figure 3a-c, CD increases with increasing of the angle of attack and decreases by increasing the Reynolds number. In order to obtain a blade profile with high aerodynamic efficiency, it is desired that the drag coefficient is minimum and the lift coefficient is maximum. It is clearly seen from Figure 3 that for all airfoils, the drag coefficient increases very little at low angles of attack (up to 5 degree), while the drag coefficient increases exponantially at higher angles of attack (above 5 degrees). As is well known, the scientific basis behind this phenomenon is the generation of drag forces due to viscous effects at low angles of attack. However, boundary layer separation occurs at higher angles of attack, and form drag (known as pressure drag) effects begin to appear as the dominant mechanism.


Re=150000
Re=500000
Re=1000000
Drag Coefficient [-]
Angle of Attack [°]
0
0.05
0.1
0.15
0.2
0
5
10
15
20

(a)


Re=150000
Re=500000
Re=1000000
Drag Coefficient [-]
Angle of Attack [°]
0
0.05
0.1
0.15
0.2
0
5
10
15
20

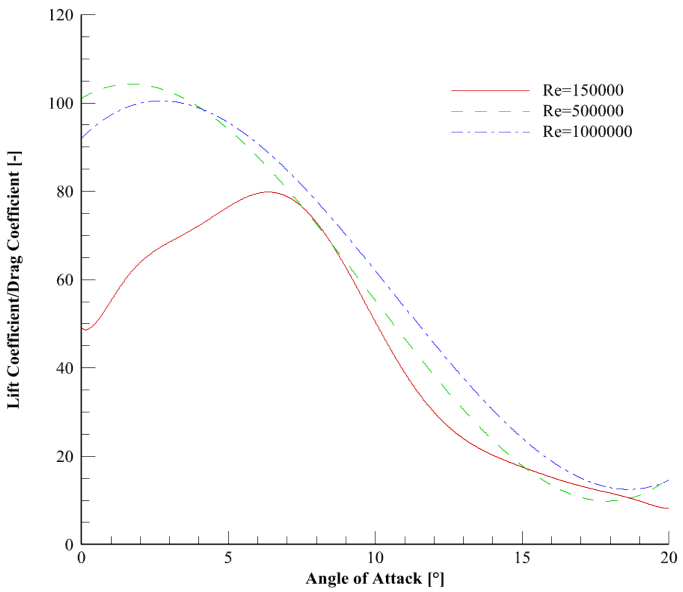
(b)



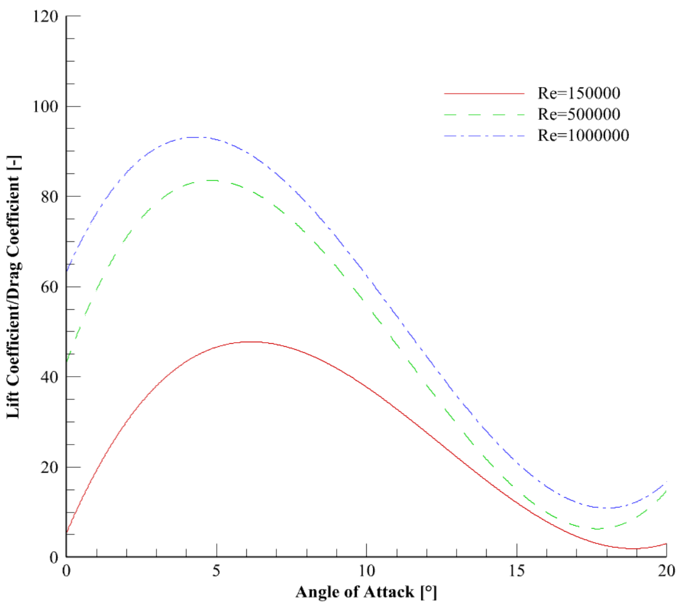
(c)

Figure 3. Change of the drag coefficient (C_D) of the blade profile with the angle of attack at different Re numbers: a- FX 63-137, b- NACA 63-415, c- NACA 6415 (Kanat profilinin sürükleme katsayısının (C_D) farklı Re sayılarında hücum açısı ile değişimi: a- FX 63-137, b- NACA 63-415, c- NACA)

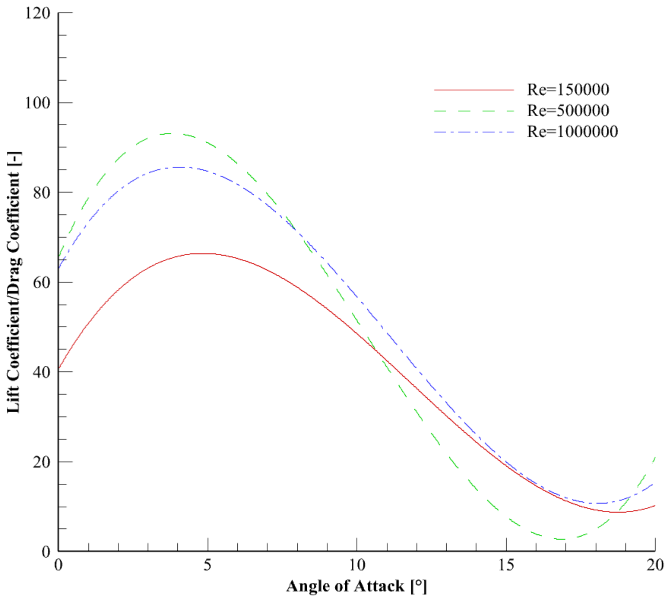
In order to the all airfoils used, figure 4 shows the relationship between lift coefficient / drag coefficient ratio, (C_L/C_D), and angle of attack for different Re numbers. As is well known, the maximum C_L/C_D ratio is required to gain the highest power from the wind turbines. Therefore, the aerodynamic performance and efficiency of the wind blade airfoil with the highest C_L/C_D ratio will also be high. In the study, the highest C_L/C_D ratio was obtained as 109.14 with FX63-137 blade profile at 3 degree angle of attack and Re number of $1x10^6$. For NACA 63-415 and NACA 6415 blade profiles, the maximum C_L/C_D ratio is as 104.28 with NACA 63-415 blade profile at 4 degree angle of attack for Re number of $1x10^6$, and is as 102.11 with NACA 6415 blade profile at 6 degree angle of attack for Re number of $1x10^6$, respectively.



(a)



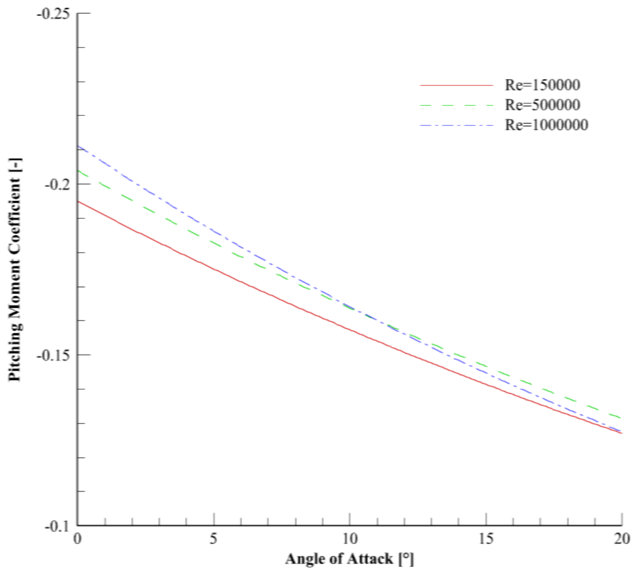
(b)



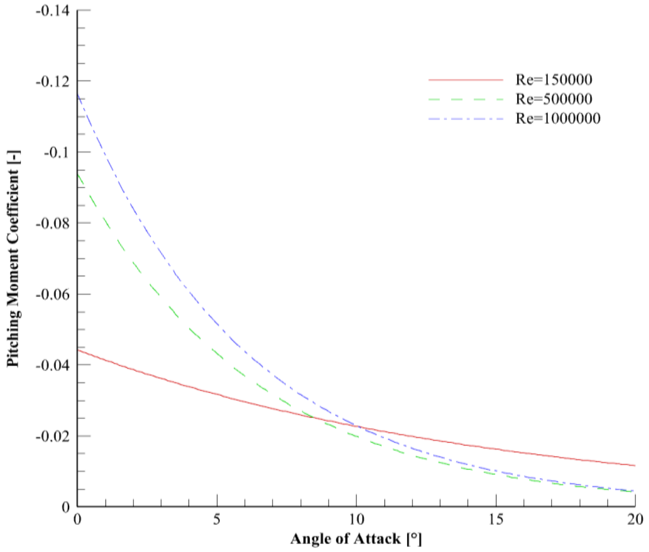
(c)

Figure 4. Change of the lift coefficient /drag coefficient ratio (C_L/C_D) of the blade profiles with the angle of attack at different Re numbers: a- FX 63-137, b- NACA 63-415, c- NACA 6415 (Kanat profilinin taşıma katsayısı/sürüklenme katsayısı oranının (C_L/C_D) farklı Re sayılarında hücum açısı ile değişimi: a- FX 63-137, b- NACA 63-415, c- NACA)

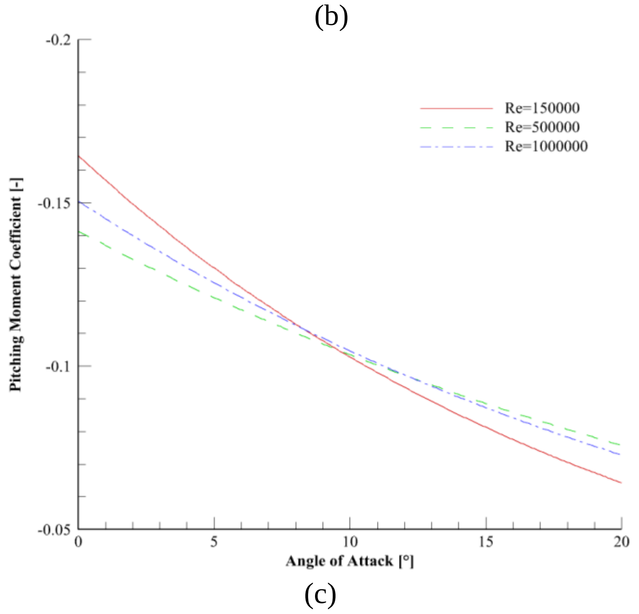
For three different blade profiles, the variation of the pitching moment coefficient with angle of attack at diferent Re numbers is shown in Figure 5. As can be clearly seen from the figure, each of the blade profiles has negative C_M values, that all blade means to be stable.



(a)



(b)



(c)

Figure 5. Change of the pitching moment coefficient (C_M) of the blade profile with the angle of attack at different Re numbers: a- FX 63-137, b- NACA 63-415, c- NACA 6415 (Kanat profilinin farklı Re sayılarında hücum açısı ile yunuslama moment katsayısının (C_M) değişimi)

Comparisons were made with similar studies on the aerodynamic performance of the same airfoils in the current literature. Table 4 shows the comparison of lift coefficient from numerical analysis with published data in the literature. Considering values given in Table 4, it is seen that the present study values are very close to published data for NACA63-415 airfoil. The lift coefficients of present study show close agreement with the published results of Ref[7]. At the same time, it can be seen that the numerical results follow the trend of the results of Lei and Zha[15] for NACA 6415 airfoil. For FX 63-137 airfoil, the current simulation results closely match with the study conducted in Ref [16] at all angles of attack. At studied airfoils, numerical results from XFLR5 also follow the same trend. Comparisons between numerical results and published data were made at Reynolds values close to each other.

Table 4. Comparison of lift coefficient with published data (Taşıma katsayısının yayınlanan verilerle karşılaştırılması)

Airfoil Profile	Angle of Attack (°)	Lift Coefficient			
		Present XFRL5	Ref [7]	Ref [15]	Ref [16]
NACA63-415	0	0.338	0.3		
	5	0.889	0.8		
	10	1.147	1.22		
NACA 6415	5	1.190		1.18	
	10	1.522		1.52	
	15	1.329		1.70	
FX 63-137	0	0.852			0.803
	5	1.3			1.328
	10	1.649			1.753

4. CONCLUSION (SONUÇ)

The study presents the aerodynamic performance of wind turbine blades including FX 63-137, NACA 63-415, and NACA 6415 at Reynolds numbers ranging from $1.5x10^5$ to $1x10^6$ and low angles of attack ($0^0 \leq \alpha \leq 20^0$). The best aerodynamic performance (the higher C_L/C_D ratio) was 109.14 with FX 63-137 blade profile at angle of attack 3 degree and $1x10^6$ Re number. The maximum C_L/C_D ratio with the NACA 63-415 blade profile was 104.28 at 4 degree angle of attack, while that for the NACA6415 blade profile was is 102.11 at the 6 degree angle of attack and $1x10^6$ Re number. According to the findings of this study, it found that FX 63-137 blade profile exhibited better aerodynamic performance than NACA 63-415 and NACA 6415. The numerical results show that the Reynolds number affects the lift, drag, and pitching moment coefficients, C_L/C_D at all angles of attack. As a result, the numerical results obtained in this study are in good agreement with the previously published studies.

In future studies, since the aerodynamic efficiency of wind turbines is largely affected by the shape of their airfoils, investigating different airfoils will enable the use of efficient airfoil geometries. With high performance wind turbine airfoils, it will be possible to obtain more energy and increase the share of renewable energy in electricity generation.

DECLARATION OF ETHICAL STANDARDS (ETİK STANDARTLARIN BEYANI)

The author of this article declares that the materials and methods they use in their work do not require ethical committee approval and/or legal-specific permission.

Bu makalenin yazarı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

***İlker YILMAZ*:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization, Methodology, Literature survey.

Yazım - inceleme ve düzenleme, Yazım - orijinal taslak, Denetim, Kavramsallaştırma, Metodoloji Literatür araştırması.

Ayşegül AVCI: Numerical analyses, Literature survey.

Sayısal analizler, literatür araştırması.

Ekin AKÖZ ARSLANKAYA: Numerical analyses, Literature survey.

Sayısal analizler, literatür araştırması.

CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study.

Bu çalışmada herhangi bir çıkar çatışması yoktur.

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