International Journal of Marine Engineering and Applications
Volume 1, Number 1, September 2024
e-ISSN: 3063-640X

Date of Received: June 23, 2024
Date of Accepted: July 4, 2024
Date of Published: September 1, 2024
DOI: doi.org/10.30649/ijmea.v1i1.365

NUMERICAL SIMULATIONS OF TURBULENT GAS-SOLID FLOW IN A GRADUAL EXPANSION

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ABSTRACT

The dwindling availability of petroleum fuels encourages the use of fuel from renewable and environmentally friendly natural resources. This study focused on the iodine value in used biodiesel methyl ester and its effect on the performance of the main components of a diesel motor, such as power, torque, brake mean effective pressure (BMEP), and specific fuel oil consumption (SFOC). Numerical research was carried out on the YANMAR TF85-MH engine model using computational fluid dynamics (CFD). The variations used are biodiesel B20, 20A, and 20B at three different engine rotation speeds: 1900 RPM, 2000 RPM, and 2100 RPM. The results show that the performance of biodiesel B20 is better compared to others. It produces 4.01 kW of power, 19.79 N.m of torque, 82065.12 Pa of BMEP, and 270.43 g/kWh of SFOC. While the B20A produces 4.61 kW of power, 20.44 N.m of torque, 84067.31 Pa of BMEP, and 288.76 g/kWh of SFOC. Then, the B20B produces 4.12 kW of power, 20.57 N.m of torque, 83244 Pa of BMEP, and 316.57 g/kWh of SFOC. So, it can be seen that the mixture of biodiesel fuel with iodine slightly affects the increase in diesel motor performance. In addition, the use of renewable energy fuels must be encouraged because their availability is maintained.

Keywords: Numerical investigation, biodiesel, motor performance, eco-friendly ship

Introduction

The fuel crisis for diesel motorbikes derived from petroleum is the biggest issue that occurs globally. To respond to this issue is to use alternative fuels, one of which is biodiesel. Biodiesel is an alternative fuel that is now increasingly being developed and can reduce the use of petroleum fuels. The development of biodiesel, apart from solving the problem of providing energy in the world, is also a hope for the future because biodiesel is based on agriculture, which will not run out as long as there are still people growing the raw material. In recent years, biodiesel has become a popular topic of conversation as an alternative material that can replace petroleum [1]. Technological advances such as the development of direct injection systems and turbocharging have made light-duty diesel-equipped motors even more enjoyable to drive. However, drastic reductions in pollutant emissions must be achieved to achieve future emission standards. This can only be done by optimizing the combustion process [2]. However, the oil crisis and global warming have caused research to be oriented toward finding suitable alternative fuels for petroleum. Now biodiesel is produced from vegetable oil, which cannot be consumed because of the high price of edible vegetable oil, becoming an alternative fuel to replace diesel oil [3].

Biodiesel is considered an effective replacement fuel to be developed. It is considered a prominent fuel because it is non-toxic, biodegradable, and renewable. Apart from that, its environmentally friendly nature is also the main reason, as well as abundant natural resources and even the existence of raw materials, which have spread globally. The raw materials needed to produce biodiesel also vary, namely soybean oil, palm oil, used cooking oil, animal fat, and several other sources [4]. Air pollution will, of course, have an impact on human health, as well as on other living creatures such as animals and plants. So that the diesel motor used does not cause excessive air pollution, research needs to be carried out [5].

Exhaust gas from the combustion process has an impact on air and environmental pollution, especially from diesel motorbikes. The diesel motor was invented in 1892 by Rudolf Diesel. The working principle of a diesel motor is to inject fuel into a combustion chamber where the air inside has been compressed. Lack of homogeneous mixing of fuel with air and high combustion temperatures cause the appearance of exhaust gases in diesel motors, for example, PM [6].

Biodiesel is an alternative fuel that has different characteristics from other fuels, therefore there is a need for experiments on exhaust gases and feasibility studies related to the greenhouse effect when used as an alternative fuel to replace fossil fuels in diesel motors, so, numerical modeling and simulation of fluid flow through the intake valve using CFD (Computational Fluid Dynamics) is the right choice of method considering the constraints mentioned previously. In this research process, it is hoped that biodiesel and methyl ester waste cooking can be used with added iodine and then simulated using computational software fluid dynamics because the addition of fuel has an effect on a more optimal diesel motor combustion process and lower exhaust gas [7].

In a diesel motor, only air is sent into the combustion chamber during induction, namely, channeling clean air into the combustion chamber (cylinder). combustion chamber (cylinder). This air is compressed during the compression stroke, and towards the end of the compression stroke, fuel is injected by the fuel injection system into the cylinder just before the desired start of combustion. Liquid fuel is injected at high speed through a small hole or nozzle at the end of the injector. The fuel is atomized into small droplets and penetrates into the combustion chamber, then evaporates and mixes with high-temperature and high-pressure cylinder air [8]. On the other hand, knowing the phenomena in the combustion chamber when the chemical combustion process occurs can help us in designing optimal combustion chamber geometry or operating the gas turbine system more efficiently. Two ways can be used to determine phenomena in the combustion chamber, namely the experimental method and the simulation method. The experimental method is a method where data collection is carried out experimentally in the field on test equipment, while the simulation method is a method that does not require direct experimentation, but is carried out by analyzing and creating simulations using CFD (Computational Fluid Dynamics) software [9] .

Recently, Computational Fluid Dynamics (CFD) has gained reliability in predicting emissions and combustion characteristics using properly calibrated and validated models. Then, CFD modeling is a very attractive alternative compared to experimental approaches, especially for diesel motor hardware optimization due to its lower requirements in terms of time and resources. Therefore, it is necessary to develop an optimization methodology based on CFD modeling that is suitable not only to define the optimal diesel motor hardware configuration/setup but also to identify qualitatively and quantitatively the most relevant effects of the variables to be optimized [11].

Research on the effect of differences in injection pressure on the amount of torque, power, and BMEP in single-cylinder diesel motors with a mixture of diesel fuel, used cooking methyl ester (JME) from coconut oil, and candlenut oil was confirmed by Francisco Pinto [12]. The results. The higher the concentration of vegetable oil in the mixture, the lower the performance of the diesel motor. Coconut oil and candlenut oil can be used as alternative ingredients to be mixed with diesel in certain mixtures. Using a mixture of used cooking oil (JME) and diesel in a ratio of 10:90 increases the effective power of a diesel motor when compared to using pure diesel fuel at rpm and load. certain. The increase also occurred in the 20:80 and 30:70 mixtures. Even with a JME fuel composition of 100% at 2000 rpm, there is an increase in the effective power of 30.34% when compared to using diesel fuel. JME will be promoted as a substitute for diesel fuel and will then be widely used as a fuel in the future [13].

However, research on exhaust gas analysis in diesel motors using waste cooking biodiesel methyl ester fuel containing iodine is still limited. So this research will be carried out with the variations used, namely biodiesel from waste cooking methyl ester (used cooking oil) with variations in iodine content with the composition B20 (a mixture of 80% diesel, 20 percent biodiesel, with no iodine) B20A (a mixture of 80% diesel, 20 percent biodiesel, 10 grams of iodine) B20B (mixture of 80% diesel, 20 percent biodiesel, 20 grams of iodine). The diesel engine speed is 1800 rpm, 1900 rpm, 2000 rpm, 2000 rpm, and 2200 rpm.

Methodology

This study uses a method utilizing the Ansys CFD program to carry out simulations. The main objective of this research is to gain an in-depth understanding of the effects of variations in engine combustion chamber design and biodiesel fuel selection on diesel engine performance. The main focus is on the effect on engine power, torque, braking mean effective pressure (BMEP), and specific fuel consumption (SFOC). In this research, the biodiesel fuel used was methyl ester (B20) without iodine, and B20 with the addition of iodine (B20A, B20B).

The data used in this research comes from previous findings that used experimental techniques to understand combustion characteristics in engines. This method involves collecting data from Ansys CFD simulation results to support the analysis carried out.

Furthermore, after the data has been collected, this research will involve using SolidWorks software to design an engine combustion chamber model and carry out simulations. By using SolidWorks, researchers will be able to visualize and analyze how different combustion chamber designs affect overall diesel engine performance.

The engine used in this research is a Yanmar TF85 MH diesel engine, which uses a Hopper water cooling system and does not use a turbo system (naturally aspirated). The components to be evaluated include the intake valve, intake manifold, exhaust valve, and cylinder of the Yanmar TF85 MH engine. Images of this diesel engine are shown in Figure 1 for analysis and evaluation purposes.

This research will also consider the use of dual-fuel diesel, by testing three different types of fuel: conventional diesel, biodiesel made from methyl ester, and biodiesel with the addition of iodine (B20, B20A, B20B). This variation aims to evaluate how the chemical composition of the fuel affects combustion efficiency and overall engine performance.

It is hoped that the results of this research will not only provide deeper insight into combustion optimization in diesel engines but also provide a basis for the development of more efficient and environmentally friendly technologies in the future. In conclusion, this research has the potential to make a significant contribution to the understanding and development of better diesel engine technology.

Figure 1. Yanmar TF85 MH. Diesel Engine

a. Modeling

Numerical research was carried out on the YANMAR TF85-MH engine model using computational fluid dynamics (CFD). SolidWorks software is used for modeling; Figure 2 shows the diesel motor combustion 3D model.

Figure 2. Diesel Motor Combustion 3D Model

b. Model Simulation Using CFD

The computational fluid dynamics (CFD) program is then used to simulate the internal combustion model of the diesel engine that was created in the previous stage. When different air and fuel mixtures are incorporated into the model, the objective is to establish the distribution of mixing speed. In this step, the location of the air inlet and outlet, as well as the intake and exhaust valves, are chosen. The biodiesel B20, B20A, and B20B geometries are listed below and can be seen in Figure 3.

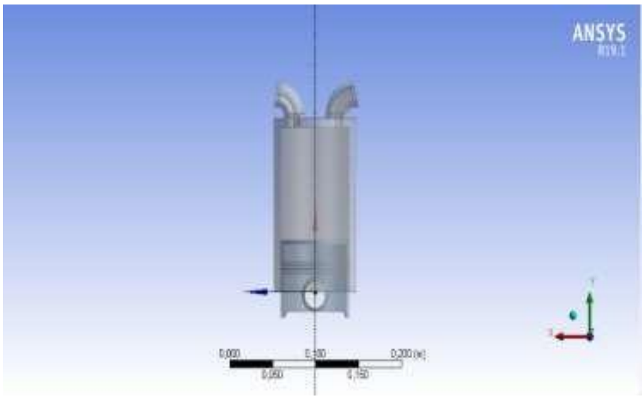

Figure 3. Biodiesel geometry stage

The meshing procedure will then be resumed. Mesh creation is a crucial step in the CFD simulation since it affects the caliber and outcome of the modeling process [14-16]. Static meshing is frequently employed in simulations for systems that are solid or immovable [17-18]. The meshing outcomes for the B20, B20A, and B20B biodiesel models are illustrated in Figure 4.

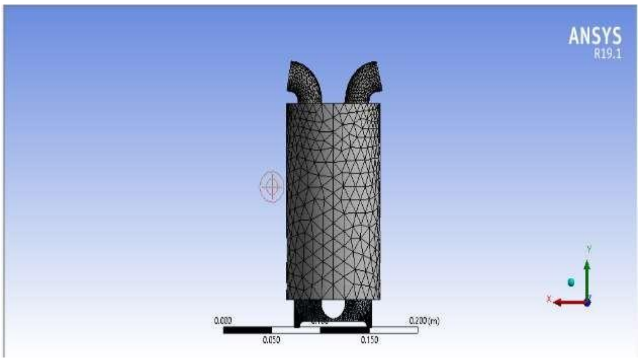

Figure 4. Biodiesel Meshing Stage

The setup stage should then be completed. This is the most crucial stage because it involves processing nearly all research parameters, including models, materials, cell zone conditions, boundary conditions, mesh interfaces, dynamic mesh, reference values, solution methods, solution controls, solution initialization, calculation activities, and calculation runs [19-21]. Figure 5 depicts the outcome of the model biodiesel B20, B20A, and B20B

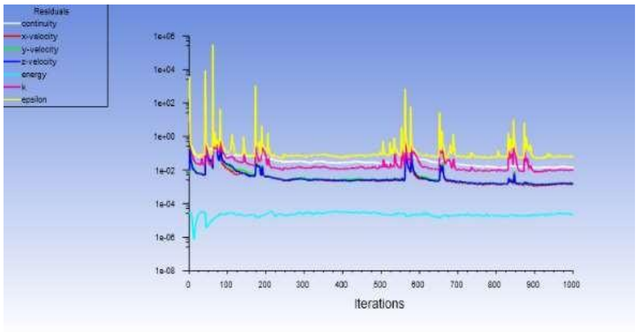

Figure 5. Residual iterations

Result and Discussion

This section examines the findings of the simulation process, data in the form of Power, Torque, Brake Mean Effective Pressure (BMEP), and Specific Fuel Oil Consumption (SFOC) per rotation of RPM, which were simulated with CFD software, particularly Ansys Fluent, at 1900, 2000, and 2100 RPM. In the results stage, we can view the outcomes of what is being examined by showing visuals, photos, and animations after the running or simulation process is complete [22].

a. B20 fuel

80% diesel and 20% biodiesel make up B20 fuel, which is variant 1 and was developed in response to the CFD stage's findings. Figure 6 depicts the combustion chamber of a diesel engine running at 1900 RPM; the pressure velocity color contour is green, and the pressure speed is 2.62 N/m. 2. While there is a pressure of -3.45 N/m2 at the inflow valve, there is a pressure of 6.01 N/m2 at the output valve. The diesel engine will experience overheating more quickly, the higher the pressure value in the combustion chamber. The fluid velocity color contour ranges from blue to red; the closer a color is to the top red, the higher the pressure or increasing pressure is. After going through the selection of several vessels, it is further determined how much power will be used on the vessel. The dimensions of the main sizes of vessels can be seen in Table 1.

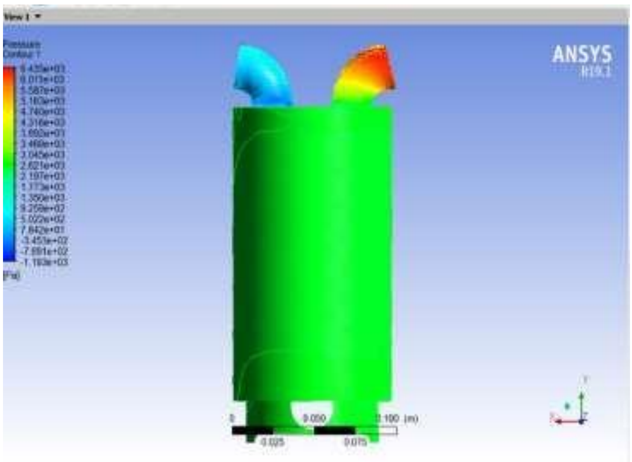

Figure 6. B20 Biodiesel Setup Stage

b. B20A fuel

Following the findings of the CFD stage, B20A fuel is variant 2, namely B20A (a blend of 80% diesel, 20% biodiesel, and 10 grams of iodine). Figure 7 depicts the combustion chamber of a diesel engine with a 1900 RPM rotation variation. The pressure speed is shown as a yellow contour with a pressure speed of 1.49 N/m2. While there is a pressure of -3.09 N/m2 at the inflow valve, there is a pressure of 6.08 N/m2 at the output valve. The combustion chamber of a diesel engine will experience overheating more quickly the higher the pressure is. The fluid velocity color contour ranges from blue to red; the closer the color is to red at the top, the higher the pressure.

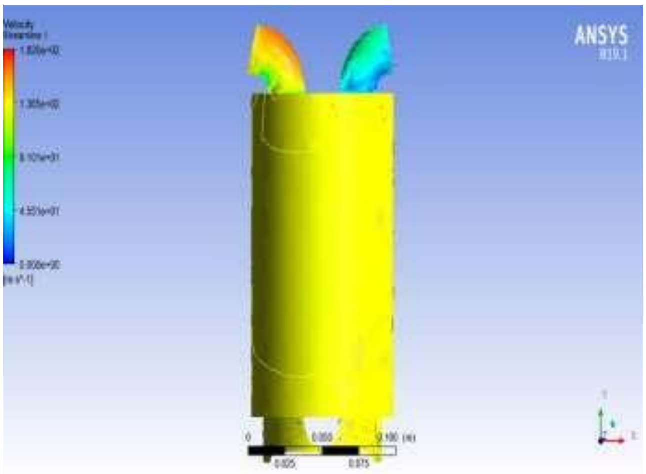

Figure 7. B20A Biodiesel Setup Stage

c. B20B fuel

B20B fuel is variation 3, (a mixture of 80% diesel, 20% biodiesel, 20 grams of iodine.

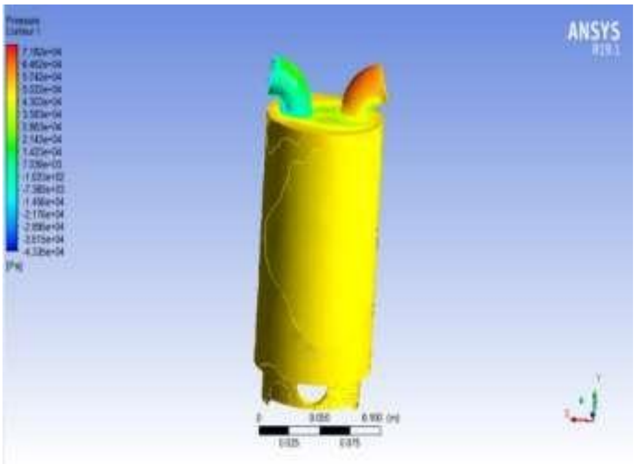

Figure 8. B20B Biodiesel Setup Stage

Diesel engine combustion chamber with a rotation variation of 1900 Rpm, the color contour of the pressure speed is yellow, the pressure speed is 4.43 N/m2. While the pressure at the inlet valve is 1.47 N/m 2, the pressure at the outlet valve of 6.45 N/m2. The greater the pressure value in the diesel engine combustion chamber, the faster it will experience overheating. The color contour of the fluid velocity is blue to red; the closer the color is to the top red, the higher the pressure.

d. Effect of Biodiesel B20, B20A, B20B on Power

The findings of the simulation demonstrate that the iodine number has an impact on the power produced by the engine at each level of rotation since the power produced by the engine at each level of load and rotation is almost the same. The biodiesels B20, B20A, and B20B are compared in Table 1. The results of the simulation show that the iodine value has no effect on engine power at any level of load and that at every level of rotation, the power generated increases along with an increase in engine speed.

Table 1. Power Comparison B20, B20a And B20b

Fuel	**1900 Rpm**	**2000 Rpm**	**2100 Rpm**
Biodiesel B20 (kW)	4.01	4.37	5.10
Biodiesel B20A (kW)	4.17	4.61	5.19
Biediesel B20B (kW)	4.12	4.63	4.99

e. Effect of Biodiesel B20, B20A, B20B on Torque

A simulation study was carried out to identify how the iodine number affects the torque produced by the engine at various rotation levels. Table 2 shows the torque produced by the engine at the highest load at each engine speed with various types of fuel. The results show that the engine produces almost the same amount of torque at the highest load at each engine speed, regardless of the type of fuel used, because the iodine number does not influence this torque.

Basically, the torque produced by the engine is not greatly influenced by the chemical characteristics of the fuel, such as the iodine number. Torque is influenced more by the design of the engine itself and other factors, such as load and engine rotation speed.

The table also shows that as engine speed increases, the torque produced tends to be inversely proportional to the rotation variation. This means that the higher the engine speed, the torque produced tends to decrease. This is a common phenomenon in engines, where the engine torque characteristics can vary depending on the engine rotation regime.

In this context, it is important to understand that although the fuel iodine number has an important role in combustion properties and its possible impact on engine performance, such as emissions or deposit formation, in the case of specific torque at certain engine speeds, the simulation results show that differences in the iodine number are not significant.

Table 2. Torque Comparison B20, B20a And B20b

Fuel	**1900 Rpm**	**2000 Rpm**	**2100 Rpm**
Biodiesel B20 (Nm)	19.79	21.07	22.31
Biodiesel B20A (Nm)	20.48	21.18	22.83
Biediesel B20B (Nm)	20.57	21.96	22.05

This research provides important insight that when evaluating engine performance, especially in terms of torque at a given engine speed, other factors such as engine design and operational load may have a greater influence than the type of fuel used. Therefore, to optimize engine performance, adjusting design and operational settings may be more crucial than considering specific chemical variations of the fuel.

f. Effect of Biodiesel B20, B20A, B20B on BMEP

The following Table 3 shows the effects of the iodine number on the BMEP generated by the engine at various rotation rates. It is well known that BMEP is basically unaffected by iodine number at each load and rotation level with different iodine variants in each type of fuel. Table 3 displays the BMEP at maximum load for each level of rotation. As can be observed, there are no appreciable differences in the types of fuel utilized at either low speed (1900 rpm) or maximum speed (2100 rpm). Additionally, it can be seen that, aside from the increase from low to high rotation, the increase in BMEP is fairly steady as the rotation increases.

Table 3. Comparison of BMEP B20, B20a And B20b

Fuel	**1900 Rpm**	**2000 Rpm**	**2100 Rpm**
Biodiesel B20 (Pa)	19.79	21.07	22.31
Biodiesel B20A (Pa)	20.48	21.18	22.83
Biediesel B20B (Pa)	20.57	21.96	22.05

g. Effect of Biodiesel B20, B20A, B20B on SFOC

The simulation findings show that the SFOC is relatively unaffected by the iodine value at each degree of load and rotation with different iodine variants in each type of fuel. There is no discernible difference between the types of fuel consumed at low speed (1900 rpm) and at maximum speed (2100 rpm), as seen in Table 4's SFOC at maximum load at each level of rotation.

Additionally, it is observed that, aside from the increase from low rotation to high rotation, the increase in SFOC is largely consistent with the higher spin.

Based on the simulation results of speed contours in the engine combustion chamber with three fuel variations, B20 biodiesel was proven to be the best choice because it showed better performance compared to other variations, namely B20A and B20B biodiesel. This simulation reveals that variations B20A and B20B experience high-pressure contours around the engine exhaust valve area. This high pressure can accelerate the occurrence of "overhead" events in the diesel engine combustion chamber, which has the potential to damage engine components, especially due to the interaction between Fe (iron) and Al (aluminum) materials.

Table 4. Comparison Of BMEP B20, B20a And B20b Sfoc

Fuel	1900 Rpm	2000 Rpm	2100 Rpm
Biodiesel B20 (g/kWh)	270.43	263.52	260.91
Biodiesel B20A (g/kWh)	288.76	291.97	273,56
Biediesel B20B (g/kWh)	316.57	274.12	253.33

The effect of the three types of fuel on engine performance is measured through the parameters power, torque, BMEP (Brake Mean Effective Pressure), and SFOC (Specific Fuel Oil Consumption). The results show significant differences in characteristics between these three types of fuel.

In terms of power, B20A biodiesel or fuel with a mixture of iodine numbers shows a striking difference compared to B20 biodiesel and other conventional fuels at engine speeds of 1900, 2000, and 2100 rpm. This suggests that the chemical characteristics of the fuel can significantly influence the engine's ability to produce power.

Meanwhile, in terms of torque, there is no significant variation between the three versions of B20 and B20A biodiesel. This shows that engine torque is not greatly influenced by the type of fuel used in this simulation.

In terms of BMEP parameters, the simulation results show slight variations between the three fuel variations at engine speeds of 1900 rpm, 2000 rpm, 2100 rpm, and 2200 rpm. This indicates that the BMEP performance of the three types of fuel does not show significant differences in the results.

Although B20 biodiesel was found to have advantages in reducing the risk of high pressure around the engine exhaust valve area, the simulation results also highlight that fuel characteristics can influence various aspects of engine performance. This study provides important insights for the development of greener fuel technologies and more efficient engine designs in the future by considering the effects of fuel variations on diesel engine performance and reliability.

Conclusion

Get the following findings based on simulation results utilizing variations in biodiesel fuel B20, B20A, and B20B using computational fluid dynamics: 1. Biodiesel outperforms B20A and B20B biodiesel in performance. 2. The power, torque, and BMEP of the engine are not considerably impacted by the iodine value. 3. At a specific rate of rotation, there is enough iodine to alter the SFOC. The power produced by the engine increases along with the rotational speed as the rotation increases. 4. With increased load and rotation, BMEP increases. 5. While there are variations in SFOC, there are none in power, torque, or BMEP at each level of rotation.

Acknowledgments

We thank the UHT marine engineering study program for launching its first journal, IJMEA; hopefully, it will be useful. thank you also for the publication of the results of this research. congratulations.

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