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IMPROVEMENT OF ECOLOGICAL PERFORMANCE OF DIESEL ENGINES BY USING MIXTURES OF CONVENTIONAL FOSSIL FUELS AND BIODIESEL

Abstract
The use of fuels from renewable energy sources is no longer a matter of individual commitment to reduce emissions contributing to air pollution from exhausts of road vehicles, but a matter of comprehensive strategy to improve the foundation and development of the global energy sector, and to provide a targeted contribution to the reduction of environmental pollution. Underlying the importance of this determination, the framework of international agreements clearly states certain objectives to be achieved in the future. However, when setting targets for increasing the scope of use of biodiesel, it is important to take into account the availability of such fuel, as well as the possibilities of its application in the existing vehicle fleet. Given the fact that sources of raw feedstock and the technology for obtaining biodiesel are still at the level that cannot cover the needs of the entire market, coupled with the fact that the existing vehicle fleet is primarily suited for the use of conventional fossil fuels, using a mixture of these two fuels can be an interim solution. This paper considers the use of fuel blends of conventional fossil diesel fuel and bio diesel in diesel-powered internal combustion engines designed for on-road applications. It analyzes the trends of energy performance (power; torque; specific fuel consumption) and environmental properties of diesel engines (emissions of polluting substances), depending on the percentage of bio diesel in fuel blends.

Key words: *biofuel blends, IC engine, performance*

1. Introduction

Numerous studies and reports by various institutes and organizations at the European and global level undoubtedly point to the negative impact of fossil fuels on the pollution of the living environment and human health, e.g. [1]. Carbon dioxide emissions are in particular focus in this context, given the fact that CO_2 emissions significantly contribute to the greenhouse effect, followed by all other gasses from the group of so-called regulated emissions.

At the global level, it has been recognized and proven that use of fuels from renewable energy sources can significantly contribute to the decrease of existing environmental pollution trends; however, there are certain limitations connected with individual energy sources from that group, in terms of their availability, technological issues, and the possibility of implementation of such fuels in individual segments of industry, or daily living in general. From the point of view of application of liquid biofuels in vehicles, primarily biodiesel, not only can such fuels be considered as having a significant potential, but we can conclude that they also represent an alternative to liquid fossil fuels.

Although the comprehensive trend of increasing biodiesel fuel production and use in EU countries is clearly and strongly positive (Figure 1), the quantities of biodiesel being placed on the market are by no means sufficient to cover the needs of the entire world, Europe, or even the European Union.

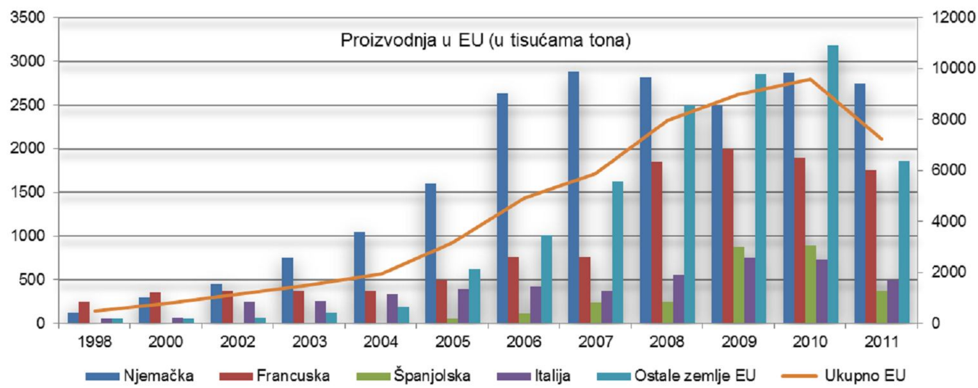


Figure 1: Trend in EU biodiesel production 1998-2011
(2011 figures are only estimations); *Source: EBB 2011*

Therefore, use of biodiesel potential includes the need to develop and implement global strategies and plans in order to ensure raw material for production, to develop production technology and technology that would enable its use in vehicles, and to develop infrastructure for biodiesel distribution beyond countries where such fuel is currently produced. In other words, increasing the popularity and level of use of biofuels must include a multidisciplinary approach, covering expert knowledge in technical, agricultural and social sciences. One of the strategies aimed at increasing the use of biofuels is the blending of biofuels with fossil fuels in a certain ratio. This paper presents the results of experimental research pointing to the potential of mixtures of fossil fuel and biofuels from the point of view of their use in IC engines, using the example of a diesel engine for use in vehicles.

2. Experimental design and boundary conditions

The testing process was based on the use of a 6-cylinder, four-stroke diesel engine, intended for use as bus engine. Table 1 includes the data on basic parameters of the tested engine.

Table 1: Basic parameters of the tested engine

Engine	Aspirated, 4-stroke engine with MAN fuel injection
Number of cylinders	6
Piston bore and stroke	125 mm x 155 mm
Displacement	11.413 dm^3
Compression	18
Static injection timing	23° CA before TDC
Nominal power	160 kW / 2200 min^{-1}
Torque	775 Nm/1400 min^{-1}

The analysis of the relevant parameters of IC engine operation was performed on the test bed in controlled conditions, at the laboratory of the TU Maribor. The testing was performed at partial and maximum load of the IC engine, and it covered the entire speed range. The so-called European Stationary Cycle (ESC) was also used in order to determine the content of exhaust gases. In order to measure physical properties, such as pressure, temperature and fuel flow, usual standardized methods for this area of testing were used [2].

Indicators of IC engine operation were determined for various mixtures of fossil diesel and biodiesel fuel (B25%; B50%; B75%). The fuels used in the process fulfilled the quality criteria defined by the relevant norms and recommendations (EN 590 norm for fossil diesel; EN 14214 norm for biodiesel). The basic characteristics of fuels used in the testing process are outlined in Table 2.

Table 2: Diesel and biodiesel properties

Fuel	Diesel	Biodiesel
Cinematic viscosity at 30 °C [mm2/s]	3.34	5.51
Surface tension at 30 °C [N/m]	0.0255	0.028
Calorific value [kJ/kg]	43,800	38,177
Cetane number [-]	45-55	>51

Different physical properties of fossil diesel and biodiesel result in certain differences in the process of forming the working mixture of fuel and air [2-4]. Differences in the properties of analyzed fuels primarily impact upon the optimal fuel injection timing [5, 6], physical processes of the mixing of fuel and air, combustion timing interval [2, 6], and that ultimately has an effect on combustion within the IC engine, and consequently on engine performance, from the point of view of obtained power and exhaust gas emissions.

In the course of testing, it was concluded that, when increasing the share of biofuel in the blend of fossil diesel and biodiesel, it is necessary to decrease fuel injection timing [7, 8], in order to reach optimal IC engine performance. The basic characteristics of analyzed fuels that contribute to this conclusion are primarily viscosity and cetane number.

According to IC engine manufacturer recommendations, optimal fuel injection timing for fossil diesel is 23° CA before TDC. The testing process that was conducted resulted in the conclusion that optimal fuel injection timing values for mixtures B75, B50 and B25 are 20° CA, 21° CA and 22° CA before TDC respectively [7].

3. Analysis of results

In order to obtain comparable data for relevant indicators of IC engine operation when using various fuel blends with optimal fuel injection timing for a given blend, changes in the cyclical delivery of fuel were used in order to maintain IC engine power at an approximately equal level. In this process, due attention was paid to ensuring that the effective utilization degree stays within the tolerance range of 3 %.

Figure 2 clearly shows that increase in the share of biodiesel in the mixture results in the increase of specific fuel consumption, as a result of lower calorific value of biodiesel.

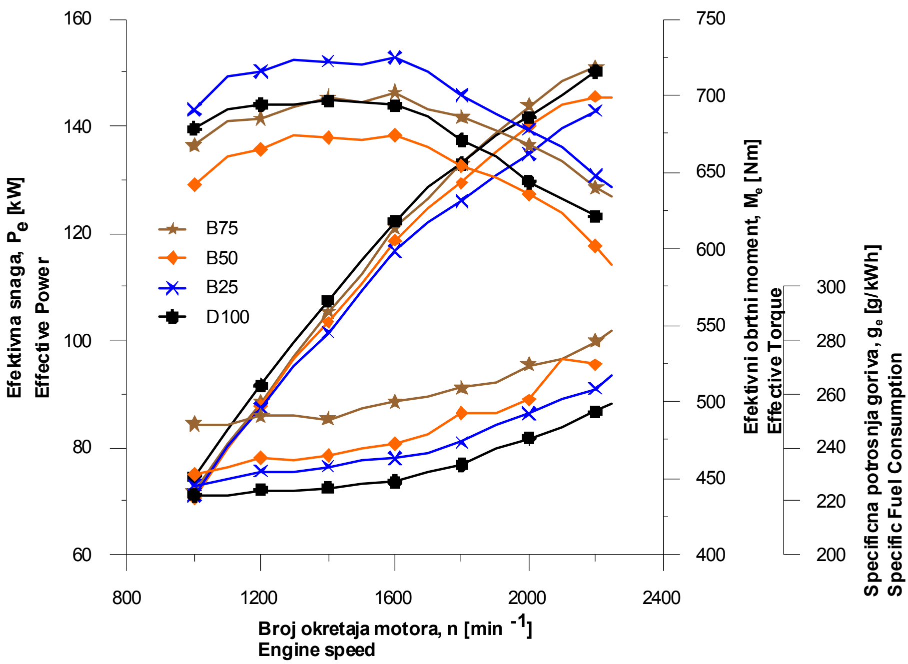


Figure 2: Effective power P_e, effective torque M_e and specific fuel consumption g_e for use of diesel and biodiesel-diesel blends with optimal injection fuel pump timing

Emissions of the most significant regulated components in IC engine exhaust (NO_x, CO, HC and soot) are shown in Figure 3. It is clear that increase in the share of biodiesel in the mixture improves the overall situation in terms of emissions, with a higher percentage of biodiesel in the blend leading to better results (with the exception of NO_x emissions, and CO emission in case of B25). Figure 3 also clearly shows that the situation is not drastically improved in case of B50 and B75 mixtures, which result in very similar indicators. Negative increase of NO_x emission accompanying the use of biodiesel can be interpreted in the context of fuel content, i.e. elevated O_2 content in biodiesel, as compared to fossil fuel.

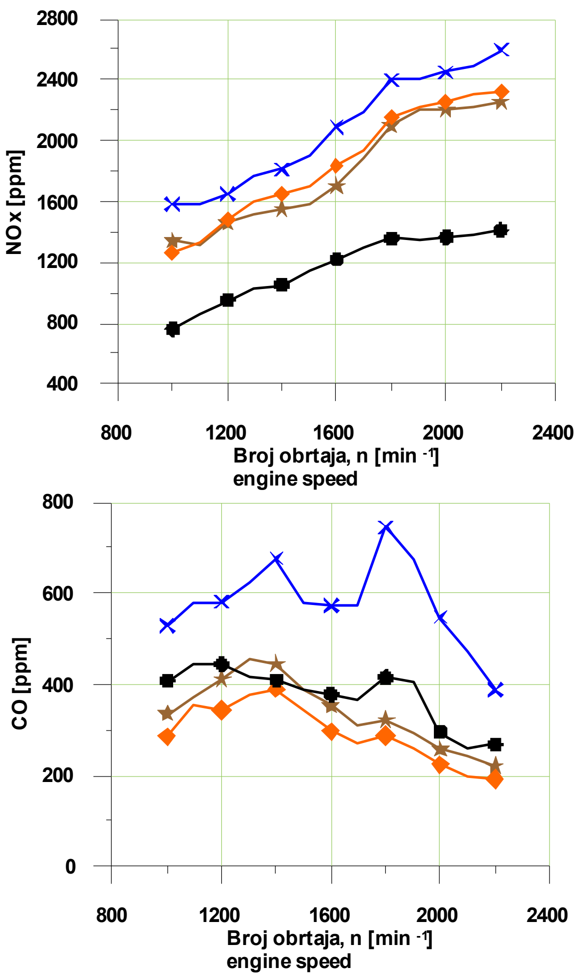
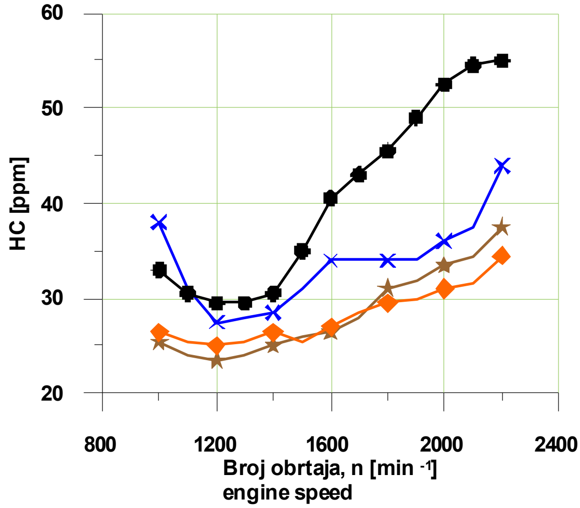


Figure 3a: Emission of the most important harmful IC engine exhaust gas components (NO_x, CO) in the case of optimal fuel injection pump timing



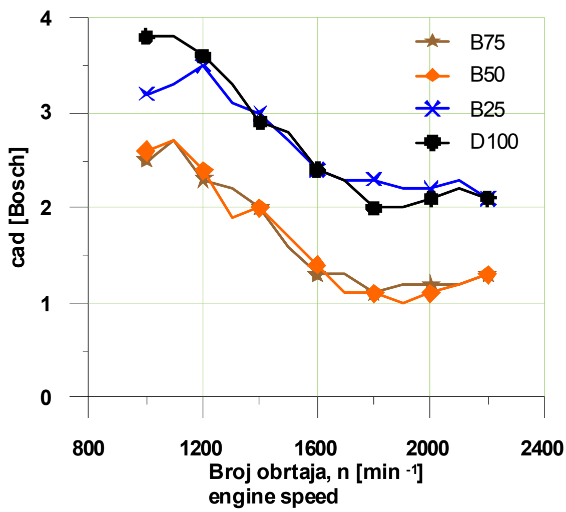


Figure 3b: Emission of the most important harmful IC engine exhaust gas components in the case of optimal fuel injection pump timing

The testing of exhaust gas emissions of IC engine using the European Stationary Cycle (ESC), including the relevant weight factors, enabled the relative comparison to be made between individual emissions, with optimal injection timing for individual blends, in comparison with the use of fossil diesel (Figure 4). As is clear from Figure 4, positive trends can be seen in terms of decrease of individual components in exhaust gasses in this case as well, and the trend is all the more clear as the percentage of biodiesel in the fuel blend increases.

Figure 4 provides an additional confirmation of conclusions stemming from Figure 3, namely that the benefit stemming from the increase of the share of biodiesel in the fuel blend from 50% to 75% is barely visible. Therefore, having in mind the aim of increasing the use of biodiesel in geographical areas where the presence of biodiesel in the market is lower, it would be possible to envisage a compromise from the point of view of optimal IC engine parameters, when using individual fuels [8]. Namely, by adjusting injection timing on the high-pressure pump to the value of 21° CA before TDC, there would be no significant loss in terms of IC engine performance (power) when using fossil diesel; however, it would be possible to use the optimal scope of IC engine operation when using a mixture with 50% of biodiesel. In such a way, one could replace the use of fossil diesel by biodiesel to a significant extent, while end users would still have the option of using fossil diesel when there is a shortage of biodiesel, without experiencing a significant drop in IC engine power. On the other hand, when biodiesel is available in sufficient quantities, that biodiesel could even be used as sole fuel, without subsequent adjustments to the fuel injection system.

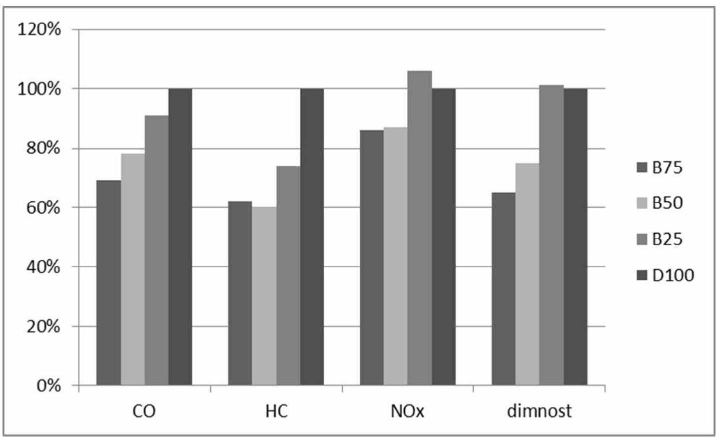


Figure 4: Relative emission of harmful components in exhaust gases of the IC engine for different biodiesel blends and optimal fuel pump injection timing

Figures 5 and 6 provide a comparison of IC engine performance when using fossil diesel, biodiesel and B50 mixture, with fuel injection timing at 21° CA before GMT. Taking into account the fact that abnormal work was not observed during IC engine testing with biodiesel blends, and taking into account the conclusions of other researchers in the area of long-term use of fossil diesel and biodiesel blends, primarily B50 blend [9], it is possible to conclude that it is indeed possible to find an optimal fuel injection timing parameter for IC engine construction for those areas where regular supply of biodiesel is not ensured, or where available biodiesel quantities are limited. Such a solution would represent a compromise from the point of view of power and emissions of individual components in ICE exhaust gasses.

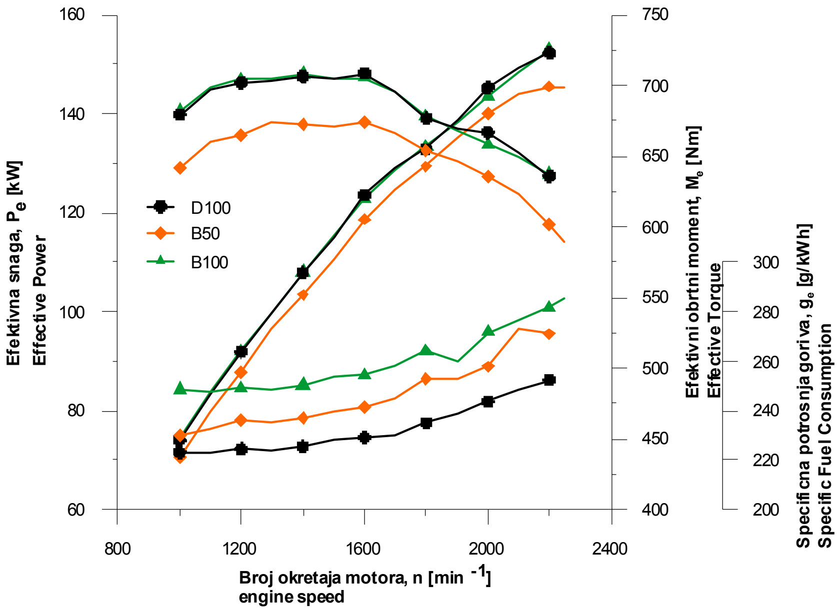


Figure 5: Effective power P_e, effective torque M_e and specific fuel consumption g_e for use of diesel-biodiesel blend B50 and biodiesel with 21°CA before TDC injection fuel pump timing

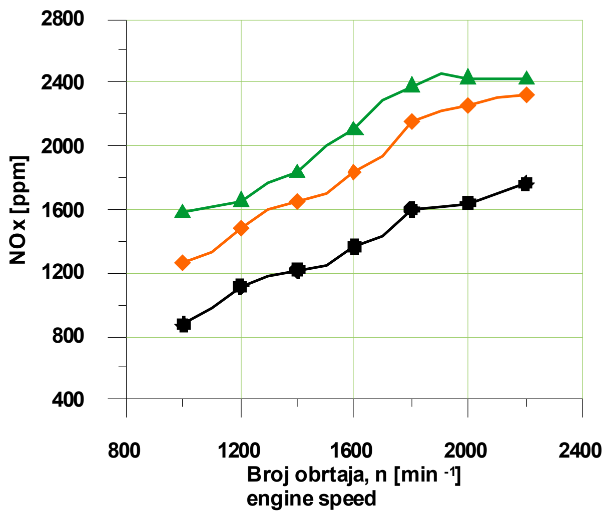


Figure 6a: Emission of the most important harmful IC engine exhaust gas components (NO_x) in the case of diesel, biodiesel and blend B50 with 21°CA before TDC injection fuel pump timing

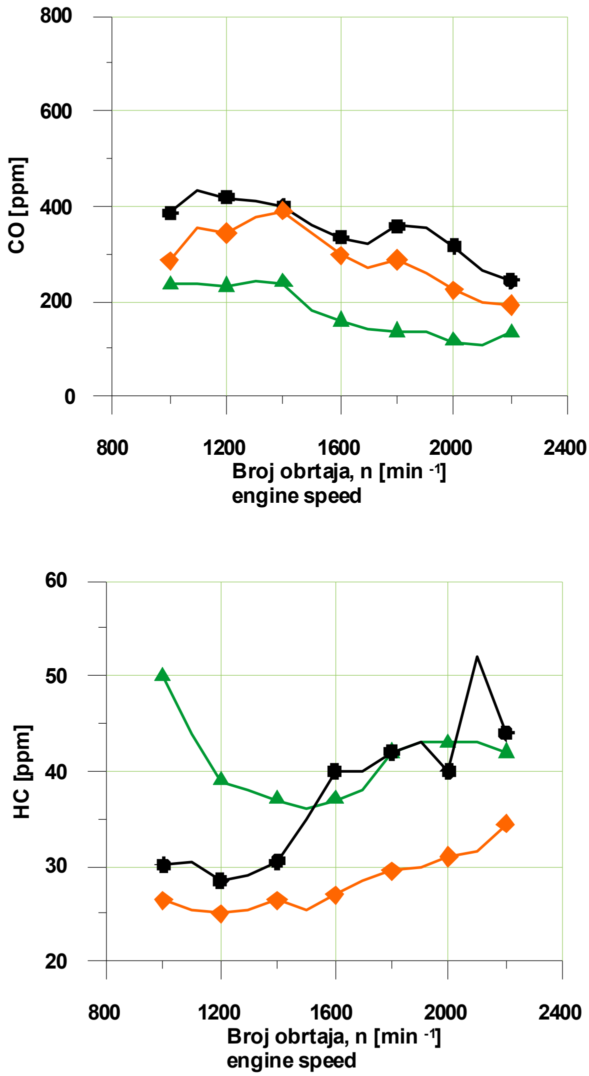


Figure 6b: Emission of the most important harmful IC engine exhaust gas components (CO, HC) in the case of diesel, biodiesel and blend B50 with 21°CA before TDC injection fuel pump timing

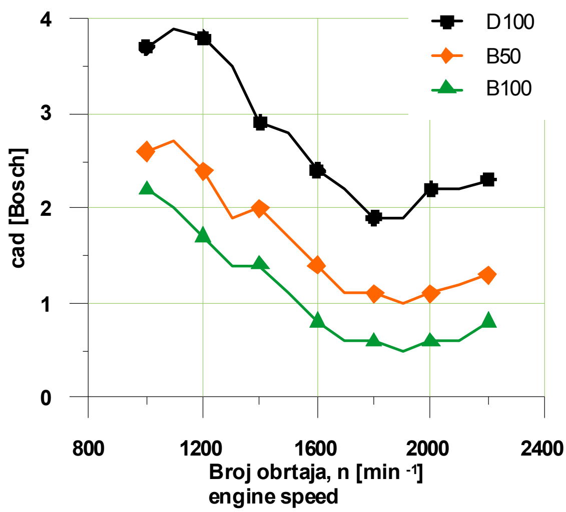


Figure 6c: Emission of the most important harmful IC engine exhaust gas components in the case of diesel, biodiesel and blend B50 with 21°CA before TDC injection fuel pump timing

4. Conclusion

The paper presented the results of research on the impact of various blends of fossil fuel and biodiesel fuel on IC engine performance, from the point of view of obtained power and emissions of individual components in exhaust gasses. When it comes to improvements in IC engine performance when using biodiesel, one benefit that can be emphasized in this context is the concentration of individual harmful components in IC engine exhaust gasses (with the exception of NO_x emissions). On the other hand, energy parameters (power, torque) can be preserved at levels close to those achieved when using fossil diesel, accompanied by an increase in the specific fuel consumption, as a result of lower calorific value of biodiesel.

It has been shown that the use of fuel blends with a high share of biofuel represents a very realistic scenario aimed at increasing the popularity and widespread use of biofuel, including in those regions where the availability of biodiesel is limited. Namely, every diesel engine can be adjusted, without major investment, for the purposes of using biodiesel, suitable blends of fossil diesel and biodiesel, or fossil diesel alone, without a significant drop in power, and without the need to subsequently adjust or reengineer the engine when changing the type of fuel used.

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