A Simulation Based Study on Diesel Engine using Different Blends of Mahua Oil and Yellow Grease in Diesel-Rk Software

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Abstract *— Biodiesels are the fuels formed using different natural materials which are freely available on the earth. With the use of these natural materials different biodiesels with different characteristics can be obtained. In the present scenario biodiesel is known to be the best replacement of fossil fuels like diesel used in automotive industries. Biodiesel can be obtained from different sources like animal oil, vegetables, plants etc. and can fulfill the required need to industry. In the current study different biodiesel blends are used in the simulation study with the use of Diesel-RK Software. Various IC Engine performance parameters were studied under this simulation which resulted in the improvement in the performance of IC Engine with less emission of toxic gases using biofuel. This study reveals various parameters affecting the performance of diesel engine.*

Keywords: *Biodiesel, Simulation, Diesel-RK, Fuel emission, IC engine.*

INTRODUCTION

In the current scenario diesel used as a fuel is on the gradual way of getting depleted so in order to save these fossil fuels a numerous biodiesel are coming into existence for providing better performance in vehicles with reduction in toxic gases[1]. With this thought of preserving the fossil fuels current study has been carried out using different biofuels which can act as a replacement for fossil fuels [2]. Though biofuels shows less efficiencies as compared to pure diesel but are highly useable as they also contribute in saving the environment by emitting less toxic gases. In the present study yellow grease and mahua oil is used for the study purpose using the DIESEL-RK simulation software. DIESEL-RK being the software provides virtual environment for performing the simulations using dif-ferent parameters and fuels [3]. The fast data processing speed has allowed DIESEL-RK to solve optimization tasks well, including optimizing the crown piston shape and fuel injection system to achieve low NOx and smoke emissions. Almost simulation-based studies for engine performance and calculation for optimization can be done very quickly with small costs in Diesel-RK.

Use of DIESEL-RK also results in cost saving as compared to experimental works carried out using the real test rig [4]. Commonly used biofuels like Karanja biodiesel are used in a Bharat Stage IV with variable compression ratio [5].

SIMULATION (DIESEL-RK)

For the simulation purpose Diesel-RK Software is utilized for obtaining the performance using two different biofuels (Mahua Oil and Yellow Grease). Fur-ther the results obtained using these biofuels are compared with results of diesel as a fuel. In RK-model of combustion, the spray is classified into seven regions, as illustrated in Fig. 1. Each region had a separate condition of evaporation and burning (Al-Dawody et al., 2019). These are:

- Free spray core.
- Front of the free spray.
- Outer sleeve of the spray.
- Near wall flow (NWF) nucleus.
- NWF on the piston surface.
- The dense front of the NWF and
- NWF Outer zone.

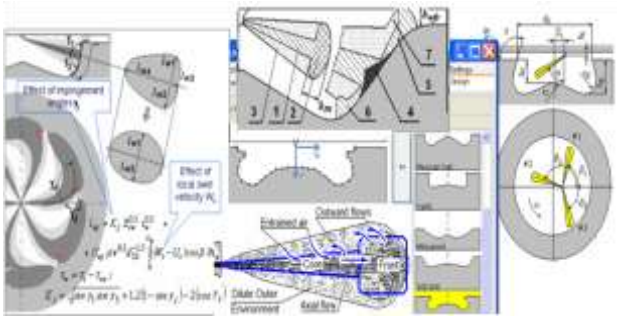


Fig 1: Spray Regions in Diesel-RK Software. (Diesel-Rk, N.D.)

Model used for Simulation

For the simulation study Kirloskar TAF 1 model was selected in DIESEL-RK software and further specifications were used as shown in table.1 below.

First the virtual environment for engine simulation was prepared in the software and different results were evaluated in the final stage of simulation and are further represented in the form of tables.

TABLE 1: SPECIFICATIONS USED IN THE SIMULATION

Engine Make	Kirloskar TAF 1
Engine type	4-Stroke, Diesel engine
Number of cylinders	1
Bore	87.5
stroke	110 mm
Cylinder capacity	0.66 L
Compression ratio	17.5
Rated power	4.4 kW, 1500 rpm
Orifice diameter	0.15 mm
Injection pressure	220 bar

Material Property

For the study on engine performance different blends were prepared using differ-ent percentage of mahua oil and yellow grease. These prepared blends were simultaneously tested in DIESEL-RK software with their properties to provide an effect on engine performance and further evaluation.

TABLE 2: MATERIAL PROPERTIES OF MAHUA OIL

Property	Pure Diesel	10 % MO	20 % MO	30 % MO	40 % MO	100 % M
Density (Kg/m^3)	830	829	835	841	847	882
Viscosity (mm^2/S)	2.72	2.4	2.7	2.8	3.0	4.2
Cetane number	48	51.6	52.2	52.8	53.4	57
Flash point (^{0}C)	67.7	64	76	88	100	170
Calorific value (KJ/Kg)	42.5	41.55	41.35	40.9	40.65	38.5

TABLE 3: MATERIAL PROPERTIES OF YELLOW GREASE

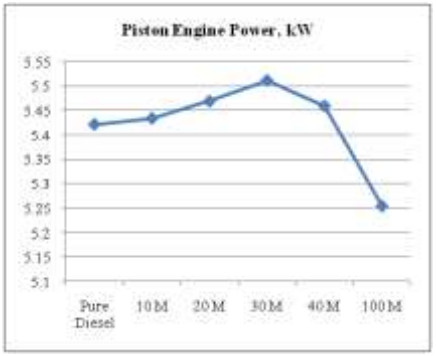
Property	Pure Diesel	10 % YGO	20 % YGO	30 % YGO	40 % YGO	100 % Y
Density (Kg/m^3)	830	839	841	844	852	885
Viscosity (mm^2/S)	2.72	3.2	3.3	3.45	3.6	4.6
Cetane number	48	47.32	48.68	49.07	49.37	51.3
Flash point (^{0}C)	67.7	76	80	84	91	170
Calorific value (KJ/Kg)	42.5	41.37	41.18	40.46	39.48	36.22

RESULTS

After the simulation process using DIESEL-RK different values of Piston Engine Power (KW), Brake torque, efficiency of piston engine, Indicated efficiency, Mechanical efficiency, Maximum Cylinder pressure, Bosch Smoke Number, CO2 g/kWh, NO g/kWh, SO2.

TABLE 4: PISTON ENGINE POWER FOR MAHUA OIL AND YELLOW GREASE FOR DIFFERENT BLEND PERCENTAGE

Parameters	Pure Diesel	10 M	20 M	30 M	40 M	100 M
Piston Engine Power, kW	5.4220	5.4341	5.4691	5.5115	5.4594	5.2551
Parameters	**Pure Diesel**	**10 YG**	**20 YG**	**30 YG**	**40 YG**	**100 YG**
Piston Engine Power, kW	5.4220	5.4415	5.6162	5.3832	5.2391	5.0114



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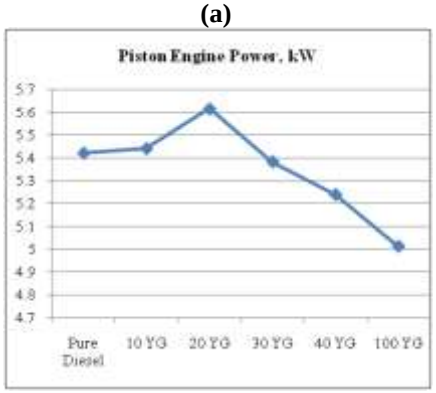

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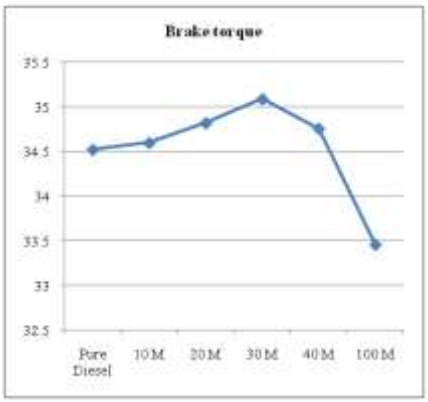
Fig 2: Piston Engine Power Obtained Using Mahua Oil (A), Piston Engine Power Obtained Using Yellow Grease (B)

Above fig. 2 shows the obtained values of piston engine power during the simulation procedure, it is observed that blend with 30% mahua oil showed the maximum values ie. 5.5115 KW. Also from the values obtained for piston engine power the trend in both the figures above showed that initially increasing the percentage of biodiesel increase the engine power and after reaching the maximum point it again decreases with further addition of biodiesel. Although addition of the biodiesel to the diesel fuel decreases its heating value, higher power was obtained in the simulation.

TABLE 5: BRAKE TORQUE FOR MAHUA OIL AND YELLOW GREASE FOR DIFFERENT BLEND PERCENTAGE

Parameters	Pure Diesel	10 M	20 M	30 M	40 M	100 M
Brake torque	34.520	34.597	34.820	35.090	34.758	33.457
Parameters	**Pure Diesel**	**10 YG**	**20 YG**	**30 YG**	**40 YG**	**100 YG**
Brake torque	34.520	34.644	35.756	34.273	33.356	31.905



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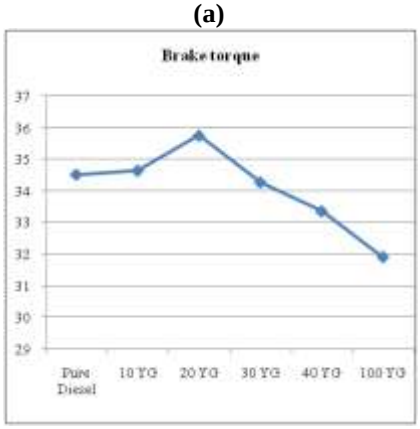

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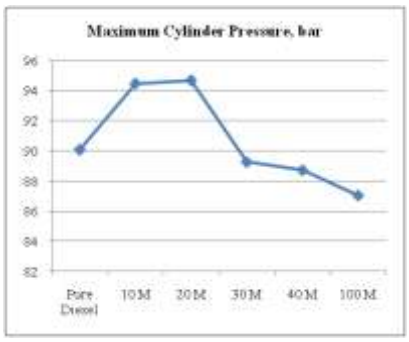
Fig 3: Brake Torque Using Mahua Oil (a), Brake Torque Using Yellow Grease (b)

Similarly like the piston power in the case of brake torque maximum values were obtained with 30% i.e. 35.090 of mahua oil and further addition of mahua oil further decrease the brake torque. Also the maximum values of brake torque in yellow grease is seen at 20% blend. The trend shown in fig. 3 for both the biodiesels showed that initially there is an increment in the brake toque with the addition of biodiesel but after a point further increment of mahua oil and yellow grease results in the decrease of brake torque.

TABLE 6: MAXIMUM CYLINDER PRESSURE FOR MAHUA OIL AND YELLOW GREASE FOR DIFFERENT BLEND PERCENTAGE

Parameters	Pure Diesel	10 M	20 M	30 M	40 M	10(
Maximum Cylinder Pressure, bar	90.070	94.467	94.678	89.254	88.712	87.
Parameters	**Pure Diesel**	**10 YG**	**20 YG**	**30 YG**	**40 YG**	**100**
Maximum Cylinder Pressure, bar	90.070	89.090	93.687	88.470	87.102	77.



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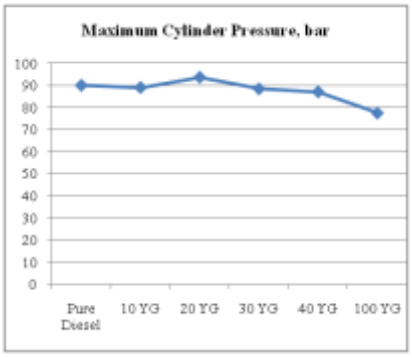

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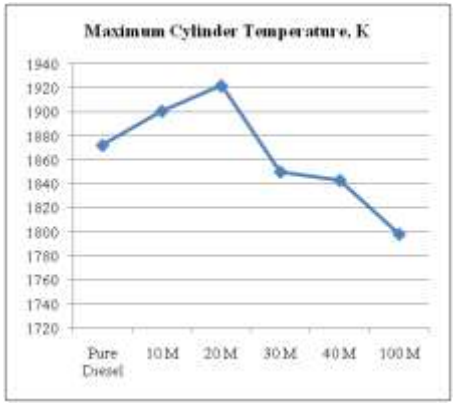
Fig 4: Maximum cylinder pressure obtained at full load condition while using mahua oil (a), maximum cylinder pressure obtained at full load condition using yellow grease (b)

At full load condition maximum cylinder pressure was evaluated to find the pressure range during the simulation procedure. Different values for maximum pressure were obtained for different blends of mahua oil and yellow grease. In the case of mahua oil maximum cylinder pressure was achieved at 20% mahua oil blend where as in the case of yellow grease maximum cylinder pressure was achieved at 20% yellow grease blend. Maximum cylinder pressure obtained with different blends of mahua oil and yellow grease ensure better heat release and smooth combustion process for the maximum value providing blends.

TABLE 7: MAXIMUM CYLINDER TEMPERATURE FOR MAHUA OIL AND YELLOW GREASE FOR DIFFERENT BLEND PERCENTAGE

Parameters	Pure Diesel	10 M	20 M	30 M	40 M	100 M
Maximum Cylinder Temperature, K	1872.3	1900.7	1921.9	1850.0	1843.1	1798.1
Parameters	**Pure Diesel**	**10 YG**	**20 YG**	**30 YG**	**40 YG**	**100 YG**
Maximum Cylinder Temperature, K	1872.3	1839.7	1917.4	1824.4	1806.5	1660.0



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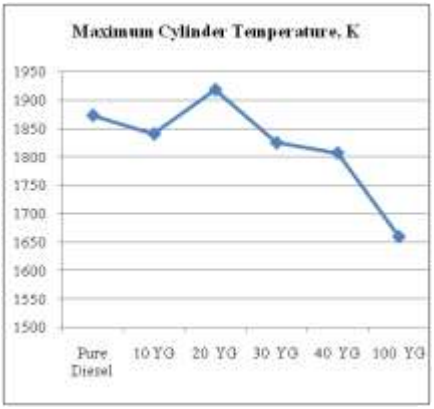

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Fig 5: Maximum temperature achieved at full load condition while using mahua oil (a), maximum temperature achieved at full load condition using yellow grease (b)

Higher temperature during the combustion process is the compulsory requirement in diesel engines. Higher temperature in the diesel engine is the result of higher performance in diesel engine. In the present study mahua oil showed the highest temperature during the simulation with 20% blend whereas in the case of yellow grease 20% blend showed the maximum temperature achieved.

TABLE 8: MAHUA OIL EFFICIENCY COMPARISON

Parameters	Pure Diesel	10 M	20 M	30 M	40 M	100 M
Efficiency of piston engine	0.35807	0.34594	0.34676	0.35004	0.34848	0.3450
Indicated Efficiency	0.42884	0.43223	0.43310	0.43432	0.43417	0.4327
Mechanical Efficiency	0.85956	0.82767	0.82786	0.83057	0.82936	0.8250

TABLE 9: YELLOW GREASE EFFICIENCY COMPARISON

Parameters	Pure Diesel	10 YG	20 YG	30 YG	40 YG	100 YG
Efficiency of piston engine	0.35807	0.35297	0.35377	0.35211	0.34951	0.33818
Indicated Efficiency	0.42884	0.42232	0.42196	0.42220	0.42059	0.40823
Mechanical Efficiency	0.85956	0.85937	0.86168	0.85839	0.85538	0.85287

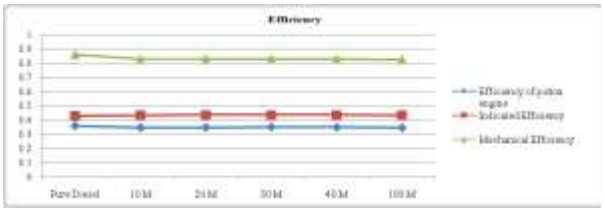


Fig 6: Different Efficiency Values Obtained in Mahua Oil for Different Blends

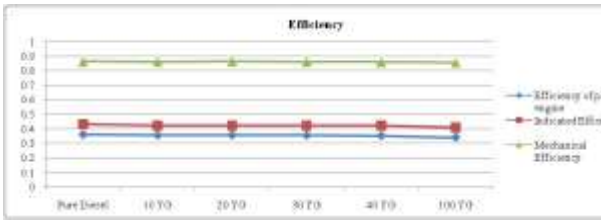
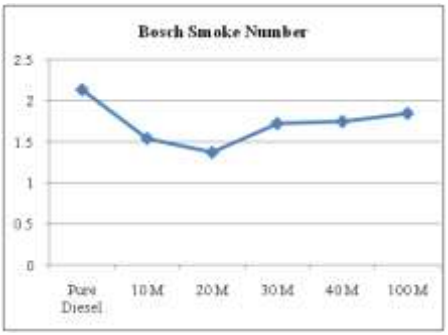


Fig 7: Different Efficiency Values Obatined in Yellow Grease for Different Blends

On comparing Fig. 5 and Fig. 6 for different efficiencies of biodiesel with different blend percent of mahua oil and yellow grease no significant changes were obtained only of variation of very less fraction has been observed in all the cases. While comparing the results obtained for different efficiencies it is observed that for piston engine efficiency maximum results were obtained with diesel as a fuel when compared with different blends of mahua oil and yellow grease. For indicated efficiency maximum efficiency is seen in blend with 30% mahua oil whereas for mechanical efficiency maximum values were obtained for yellow grease i.e. with 20% blend.

TABLE 10: BOSCH SMOKE NUMBER (BSN) FOR MAHUA OIL AND YELLOW GREASE WITH DIFFERENT BLEND PERCENTAGE

Parameters	Pure Diesel	10 M	20 M	30 M	40 M	100 M
Bosch Smoke Number	2.7674	1.5454	1.3772	1.7265	1.7504	1.8486
Parameters	**Pure Diesel**	**10 YG**	**20 YG**	**30 YG**	**40 YG**	**100 YG**
Bosch Smoke Number	2.7674	2.3043	2.2420	2.2777	2.3037	2.9968



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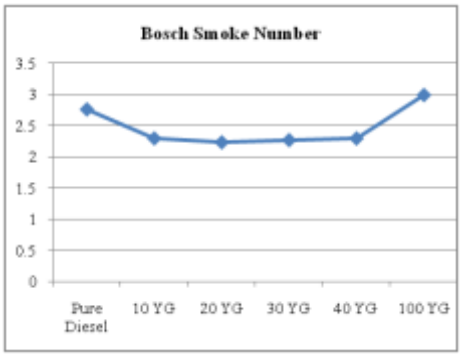


(b)

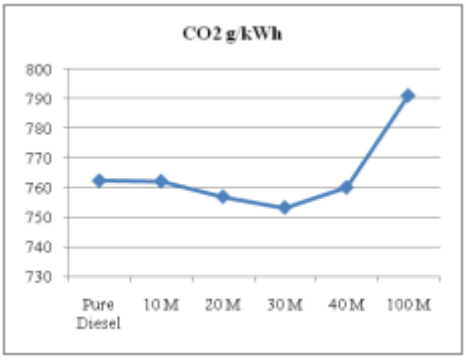
Fig 8: Bosch Smoke Number For Mahua Oil (a), Bosch Smoke Number For Yellow Grease (b)

Minimum values of bosch smoke number in the working of diesel engine means the minimum emission during the combustion process. Higher values of bosch smoke number are the result of environmental pollution with higher emission of toxic gases. So the biodiesel needs to be first tested for bosch number before its free use in diesel engines. In the case of mahua oil minimum values of bosch smoke number is seen at 20% blend where as in the case of yellow grease also showed the minimum values of bosch smoke number but with

higher difference as compared to mahua oil values.

TABLE 11: CO2 EMISSION FOR MAHUA OIL AND YELLOW GREASE WITH DIFFERENT BLEND PERCENTAGE

Parameters	Pure Diesel	10 M	20 M	30 M	40 M	100 M
CO2 g/kWh	770.70	762.08	756.85	753.17	759.99	791.11
Parameters	**Pure Diesel**	**10 YG**	**20 YG**	**30 YG**	**40 YG**	**100 YG**
CO2 g/kWh	770.70	764.43	736.12	772.90	793.93	841.55



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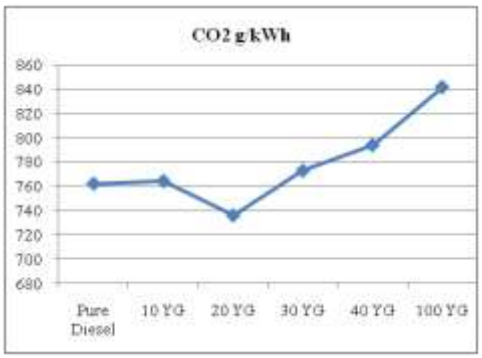


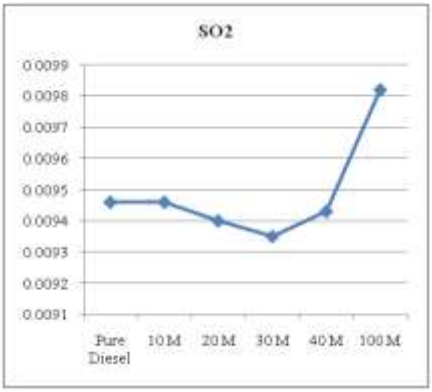
(b)

Fig 9: CO_2 Emission For Mahua Oil (a), CO_2 Emission For Yellow Grease (b)

Biodiesel also has some emissions benefits, which can result in reduction of toxic gases produced at the time of combustion in engine. In the study with different blend percentages of mahua oil and yellow grease as a biofuel it was observed where minimum emission of CO_2 was seen in 30% mahua oil blend and in the case of yellow grease 20% blend showed the minimum values of CO_2 emission. Higher emission of CO_2 in diesel engines can result in causing higher environmental pollution.

TABLE 12: SO_2 RELEASE FOR MAHUA OIL AND YELLOW GREASE WITH DIFFERENT BLEND PERCENTAGE

Parameters	Pure Diesel	10 M	20 M	30 M	40 M	100 M
SO2	0.00946	0.00946	0.00940	0.00935	0.00943	0.0098
Parameters	**Pure Diesel**	**10 YG**	**20 YG**	**30 YG**	**40 YG**	**100 YG**
SO2	0.00946	0.00786	0.00491	0.00765	0.01075	0.0293



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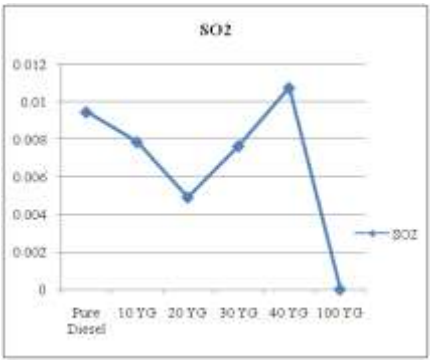

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Fig 10: SO_2release for Mahua Oil (a), SO_2release For Yellow Grease (b)

Sulphur present in diesel and biodiesel is the result for release of SO_2 from the diesel engines. SO_2 is also placed under the category of toxic emissions where minimum values were obtained at 30% mahua oil and in case of yellow grease 20% yellow grease showed the least values of SO_2release during the simulation process.

CONCLUSION

From the overall study it can be concluded that both yellow grease and mahua oil can be used as a biodiesel for the engine as a fuel as both materials showed overall better performance than pure diesel. Bio diesel blends showed greater significance in decreasing the emission of toxic gases as compared to pure biodiesel. Overall, from this study it can be concluded that replacement of diesel which is a fossil fuel and is on the stage of getting exhaust can be replaced with different biodiesels which will benefit both industrially and environmentally.

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