

Forklifts complying with European Stage V Non-Road Emission Standards (EU Stage V) (2.0t to 3.5t/3.5t to 5.5t)



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Mitsubishi Logisnext Co., Ltd. sells engine-powered forklifts that conform to the regulations on environmentally hazardous substances in each country and readily offers new models developed to meet tougher standards whenever new regulations are introduced. As diesel engine forklifts that are compliant with the world's most stringent regulations on environmentally hazardous substances of concern (European Stage V Non-Road Emission standards, hereinafter European Stage V Standards), we have developed and launched 2.0t to 3.5t/3.5t to 5.5t forklifts powered by diesel engines with a new-type diesel particulate filter (DPF). The details are presented below.

1. Introduction

In the European market, the European Stage V Standards came into effect in January 2019 for engine-powered forklifts. We therefore developed 2.0t to 3.5t/3.5t to 5.5t forklifts that meet the new emission standards. The applicable standards are characterized by newly-proposed particulate number (PN) limits in exhaust gas, in addition to setting stricter limits on substances that have been under regulation such as hydrocarbons (HC), nitrogen oxides (NO_x) and particulate matter (PM). To meet the PN standards, engines need to be equipped with a DPF, thus necessitating the process of regenerating the DPF by burning the collected soot during engine operation. Therefore, we have successfully developed a forklift with DPF regeneration control without requiring customers to compromise forklift operability/workability or suspend work in progress for the regeneration process.

2. About the European Stage V Standards

The European Stage V Standards are applicable to engines fueled by gasoline, LPG or diesel, and the prescribed limits vary depending on the engine power P (kW). This report focuses only on diesel engines, which are relevant to our new products. Being equipped with a 36.0 kW engine, our 2.0t to 3.5t forklifts fall under the category of $19 \leq P < 37$ (kW), while the 3.5t to 5.5t forklifts are placed under the category of $37 \leq P < 56$ (kW) as their engine power is 55.0 kW.

Table 1 shows the emission limits by engine power category, before and after the implementation of the Stage V standards. The new standards are characterized by the addition of PN limits in exhaust gas.

Table 1 European Stage V Non-Road Emission Standards

Engine power (kW)	Emission stage (implemented prior to Stage V)	Current emission limits					
		CO (g/kWh)	HC (g/kWh)	NO _x (g/kWh)	HC+NO _x (g/kWh)	PM (g/kWh)	PN (1/kWh)
19 ≤ P < 37	Stage III A	5.5	—	—	7.5	0.6	—
37 ≤ P < 56	Stage III B	5.0	—	—	4.7	0.025	—
56 ≤ P < 130	Stage IV	5.0	0.19	0.4	—	0.025	—
130 ≤ P < 560	Stage IV	3.5	0.19	0.4	—	0.025	—



Engine power (kW)	Stage V emission standards					
	CO (g/kWh)	HC (g/kWh)	NO _x (g/kWh)	HC+NO _x (g/kWh)	PM (g/kWh)	PN (1/kWh)
19 ≤ P < 37	5.0	—	—	4.7	0.015	1 × 10 ¹²
37 ≤ P < 56	5.0	—	—	4.7	0.015	1 × 10 ¹²
56 ≤ P < 130	5.0	0.19	0.4	—	0.015	1 × 10 ¹²
130 ≤ P < 560	3.5	0.19	0.4	—	0.015	1 × 10 ¹²

Source: REGULATION (EU) 2016/1628 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 September 2016

3. Advantages and features of forklifts equipped with a DPF

In general, engines with a DPF require to be operated in DPF regeneration mode in which a certain high level of exhaust gas temperature is maintained to burn the collected soot. However, as forklifts have considerable fluctuations in load and engine speeds, it is difficult to acquire stable conditions for DPF regeneration. Therefore the customers may require to interrupt their daily workflow for some time while the DPF is regenerated.

However, as forklifts are machines used for work, customer needs lie in maintaining machine availability. We challenged to enable DPF regeneration without decreasing machine availability.

Our goal was the realization of DPFs that automatically regenerate in the daily workflow of our customers. The forklift layout was designed in collaboration with Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. (MHIET), which was in charge of developing the engine. The keys to successful DPF regeneration control are to have a layout that can minimize the temperature decrease of exhaust gas from the forklift's exhaust pipe and to control the engine in such a way as to create suitable conditions for DPF regeneration including exhaust gas temperature. At the stage of engine development, the trial forklift was used to collect engine/DPF data under the on-board conditions. Our DPF control system, which was designed based on these obtained results of various actual operations, has enabled DPFs to be regenerated under a wide range of operation patterns.

For DPF control, we initially intended to install a DPF in the vicinity of the engine exhaust port, in order to minimize the exhaust gas temperature decrease that can occur between the engine exhaust port and the DPF. However, we found it difficult to realize such a layout because the engine room of small forklifts was spatially very limited. The issue was eventually solved as shown in **Figure 1**, in which an unused space away from the engine is utilized. This layout has become possible by improving the design of the exhaust pipe between the engine exhaust port and the DPF to limit the exhaust gas temperature decrease to the greatest extent possible (for example, by preventing the influence of engine cooling air or using insulating materials), as well as by developing the engine based on the exhaust gas temperature decrease data obtained by the trial forklift.

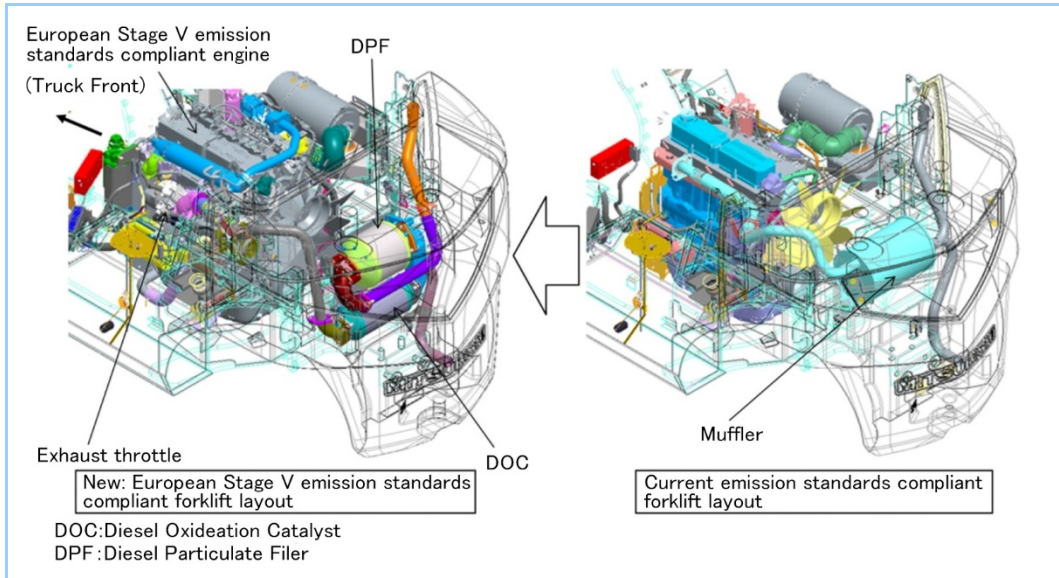


Figure 1 DPF layout for 2.0t to 3.5t forklifts

Before the sales in European market, in order to verify the performance, we asked some of our European customers to use the new forklifts installing an engine data logger and we remotely monitored. The results have verified that DPFs can be regenerated even in the forklift unique operation condition of low engine load and fewer engine speeds, which are unfavorable for DPF regeneration. **Figure 2** presents some examples of the engine operation patterns of our customers who frequently use DPF at low engine load and low speed.

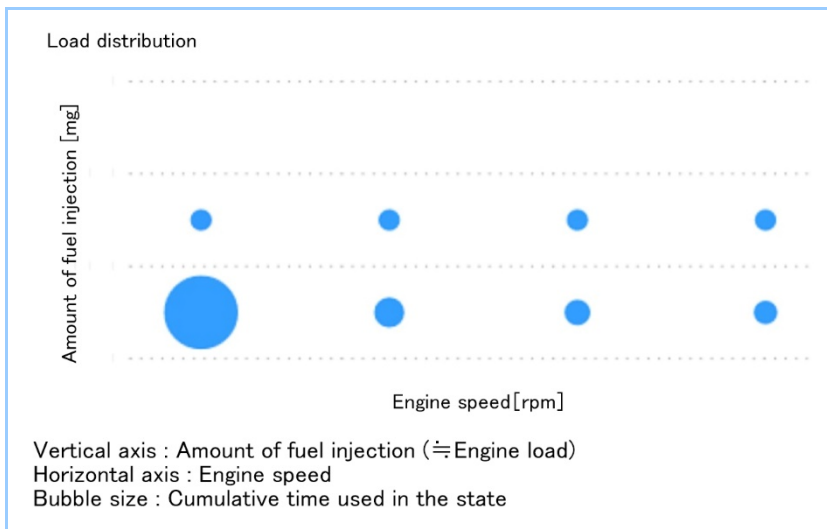


Figure 2 Examples of engine operation patterns

4. Main specifications and brand development

Table 2 lists the main specifications of our newly developed forklifts.

Table 2 Main specifications

Forklift model			FDE 20	FDE 25	FDE 30	FDE 35	FDE 40	FDE 45	FDE 50C	FDE 50	FDE 55	
Performance	Load capacity	Rated	kg	2000	2500	3000	3500	3500	4000	4500	5000	5500
	Load center distance		mm	500	500	500	500	600	600	600	600	600
	Travel speed	Empty	km/h	17.5	17.5	17	18	22.5	22.5	22	22	22
	Drawbar pull (Loaded)	Maximum	N	18600	18600	18200	17100	36700	36000	35700	35800	35900
		at 1.6km/h	N	16200	16100	15800	14800	26000	25600	25000	24800	24500
	Maximum gradeability (Loaded)	at 1.6km/h	%	31	27	22	18	29	26	22.9	21	19.3
	Lifting speed	Loaded	mm/sec	610	610	490	410	620	620	540	530	530
		Empty	mm/sec	640	640	510	430	670	670	580	570	570
	Lowering speed	Loaded	mm/sec	500	500	500	500	500	500	500	500	500
		Empty	mm/sec	500	500	500	500	500	500	500	500	500
Minimum outside turning radius		mm	2200	2230	2380	2440	2580	2730	2760	2890	2940	
Noise level		dB(A)	79	79	79	79	78.5	78.5	78.5	78.5	78.5	
Dimensions	Overall length to fork face		mm	2485	2560	2735	2795	3000	3130	3170	3310	3360
	Overall width		mm	1150	1150	1275	1290	1415	1460	1460	1460	1460
	Overall height	Overhead guard	mm	2145	2145	2165	2175	2296	2296	2296	2296	2296
		Mast	mm	2150	2150	2170	2300	2320	2320	2400	2400	2400
	Tread width	Front	mm	960	960	1060	1060	1175	1175	1175	1175	1175
		Rear	mm	980	980	980	980	1180	1180	1180	1180	1180
	Truck weight	Empty	kg	3490	3790	4430	4820	5960	6370	6880	7340	7670
Wheelbase		mm	1600	1600	1700	1700	1850	2000	2150	2150	2150	
Engine	Supplier		MHIET				MHIET					
	Model		D04EG				D04EGT					
	Output		36kW				54kW					
	Displacement		3,331cc				3,331cc					
	Intake system		Naturally intake				Turbocharged					
	After-treatment		DOC,DPF				DOC,DPF					
	Power train		Torque converter				Torque converter					

Our newly-developed DPF engines are incorporated into the models of the following four brands: Mitsubishi brand, CAT brand, Unicarriers brand and TCM brand (**Figure 3**).



Figure 3 Engine-powered forklifts of each brand

5. Future development

The megatrend in the forklift market is to shift to electric or battery-powered forklifts. However, engine-powered forklifts are expected to remain in demand, especially in areas where swift electrification is unlikely because of a poor power situation or for use in work environments in which engine-powered forklifts are preferable.

User needs for engine-powered forklifts include better environmental performance, enhanced safety features and the handling of cargo with higher efficiency. We will further improve customer satisfaction by providing functionality that is difficult to realize using battery-powered forklifts.