Testing on Engine 21126

REPORT ON TESTING DEVICES R3 AND R7 FROM CTP

The purpose of these tests is to study the effect of R3 and R7 on changes in engine fuel consumption and its environmental performance.
The complex of test was carried out in accordance with the test program PM-03/2024-04

List of abbreviations and symbols

The following abbreviations and designations are used in this research report:

ESC – external speed characteristic

Engine – Internal combustion engine V-21126 with Bosch M7.9.7 electronic system of engine control.

TP – Test program PM-03/2024-04

Introduction

The objective of this work is to test prototypes of R3 and R7 devices manufactured by CTP (hereinafter referred to as the prototype) installed on the fuel system elements and electrical wiring of a test stand based on the V-21126 engine, in order to study the influence of the prototype on changes in engine fuel consumption and its environmental indicators.

Experimental studies are performed in accordance with the agreed test program PM-03/2024-04 (hereinafter referred to as the test program).

1 Description of the experimental stand

Test of the prototype are carried out on a test stand, which includes V-21126 engine (hereinafter referred to as the internal combustion engine (Figure 1.1) and hydraulic loading device SuperFlow SF902 (Figure 1.2).

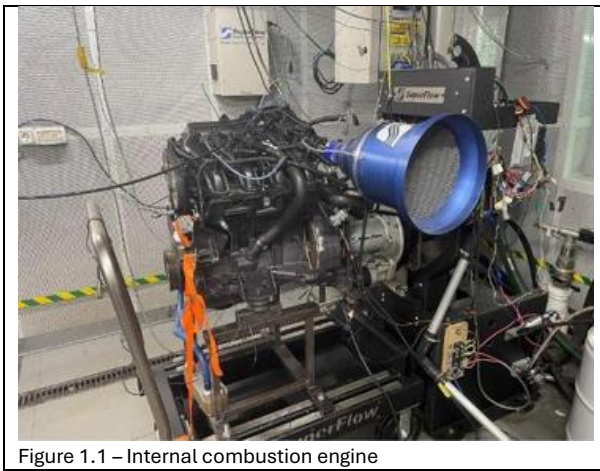

Figure 1.1 – Internal combustion engine

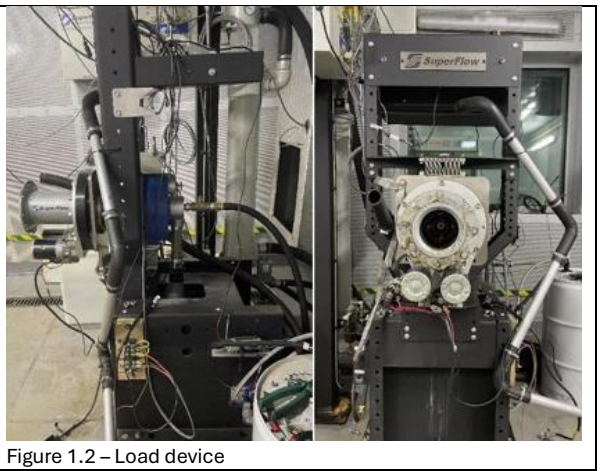

Figure 1.2 – Load device

The main characteristics of the internal combustion engine are presented in Table 1.1

Parameter	Value
Type	Inline, 4-cylinder
Order of operation of cylinders	1-3-4-2
Cylinder diameter, mm	82
Stroke, mm	75.6
Displacement, L	1.597
Compression ratio	11:1
Rated power, KW (hp)	72 (98)
Rated speed of rotation of the crankshaft, rpm	5600
Volume of the lubrication system, l	3.5
Electronic system of engine control	Bosch M 7.9.7

Table 1.1 – Characteristics of the V-21126 engine

The internal combustion engine installed on the stand was equipped with the necessary data meter and metering device necessary for determining the required engine parameters, as well as monitoring its performance:

- K-type rod thermocouples for exhaust gas temperature measurement (Fig 1.3)
- turbine-type fuel consumption sensor (Fig 1.4)
- Intake air flow meter (Figure 1.5)

Figure 1.3 – Rod thermocouples

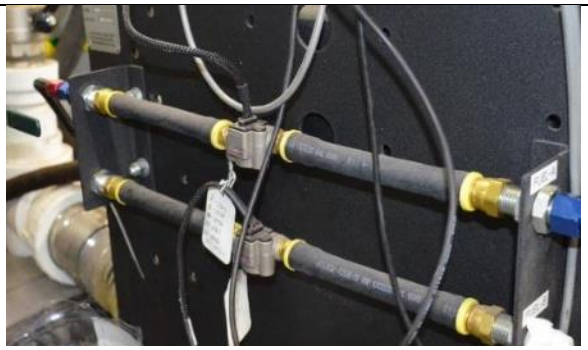

Figure 1.4 – Fuel consumption sensor

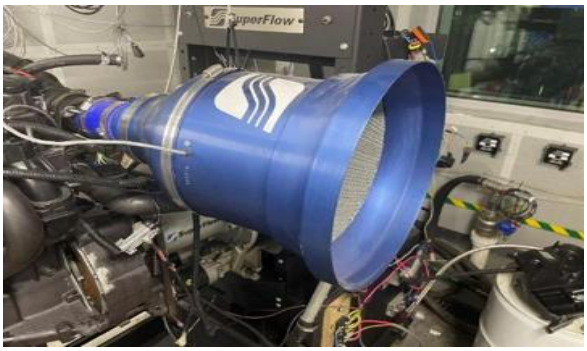

Figure 1.5 – air flow meter

95 octane gasoline was used as fuel.

Engine oil 5W-40

Cooling liquid-antifreeze

The engine is stared by a starter that is part of the stand.

Sensors are installed in the box that records environmental parameters: Pressure, temperature, humidity

Engine speed, torque, power, fuel, consumption, atmospheric pressure, air temperature, relative humidity, exhaust gas and coolant temperature, etc. were monitored from the test bench and from the control panel of the load device (Figures 1.7-1.8

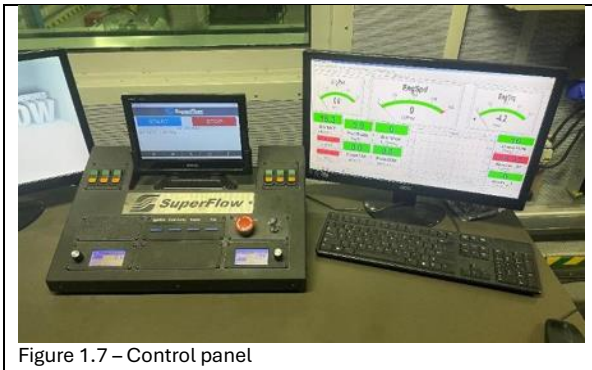

Figure 1.7 – Control panel

Figure 1.8 – Stand Operator Monitor

2. Study of the influence of the R3 and R7 devices.

During the tests, the parameters of the engine were analysed first without R3 and R7 devices, and after with R3 and R7. After that comparison was made.

The parameters recorded as part of the test data, as well and calculated during the analysis, are presented in Table 2.1

#	Parameter Name	Units
1	Speed of rotation	min^{-1}
2	Throttle position	%
3	Power	HP
4	Power	KW
5	Torque	Nm
6	Fuel consumption (stand)	g/min
7	Fuel consumption (weight	g/min
8	Specific fuel consumption	g/KWh
9	CO	%
10	CO_2	%
11	Ch	mln^{-1}
12	O_2	%
13	λ	

Table 2.1 – Measured parameters

After starting and warming up the engine (the coolant temperature is above 60°C), it was brought to operating mode an parameters were recorded.

The stand software records the values of the parameters actually measured and also the values calculated.

Based on the result of the first part of the tests, a set of parameter values was obtained for construction the external speed characteristic (hereinafter referred to as ESC). For more information, see Appendix Table A1

At the second stage, fuel consumption and environmental parameters were determined. Tabel 2.2 and 2.3 show the values of the parameters.

#	Parameter Name Mesurement	Units	Value							
			#1		#2		#3		#4	
1	Speed of rotation	min^{-1}	2503	2502	2570	2496	3498	3498	3500	3499
2	Throttle position	%	40	60	40	60	40	60	40	60
3	Power	HP	36.6	39.6	35.6	36.6	53.2	62.9	50.4	60.7
4	Power	KW	27.0	29.2	26.2	27.0	39.0	46.4	37.1	44.7
5	Torque	Nm	103.0	111.4	97.7	103.2	106.8	126.7	101.3	122.2
6	Fuel consumption (stand)	g/min	138.0	144.0	126.0	132.0	198.0	228.0	174.0	204.0
7	Specific fuel consumption	g/KWh	306.7	295.9	288.1	293.6	304.6	294.8	281.0	273.6

Table 2.2 – Determination of parameters in steady-state modes

#	Parameter Name	Units	Value			
1	Speed of rotation	min^{-1}	2570	2496	3500	3499
2	Throttle position	%	40	60	40	60
3	Power	HP	35.6	36.6	50.4	60.7
4	Power	KW	26.2	27.0	37.1	44.7
5	Torque	Nm	97.7	103.2	101.3	122.2
6	Fuel consumption (stand)	g/min	126.0	132.0	174.0	204.0
7	Fuel consumption (weight	g/min	118.0	133.0	171.0	207.0
8	Specific fuel consumption	g/KWh	269.8	295.8	276.2	277.6
9	CO	%	2.341	1.847	4.485	3.612
10	CO_2	%	14.56	14.79	14.35	14.43
11	Ch	mln^{-1}	201.0	204.0	153.0	125.0
12	O_2	%	0.954	0.658	0.561	1.286
13	λ		1.058	1.042	1.031	1.026

Table 2.3 – Determination of fuel consumption and environmental parameters

Similarly to the steps described above, tests were performed with the installed R3 and R7 (Figure 2.2-2.3)

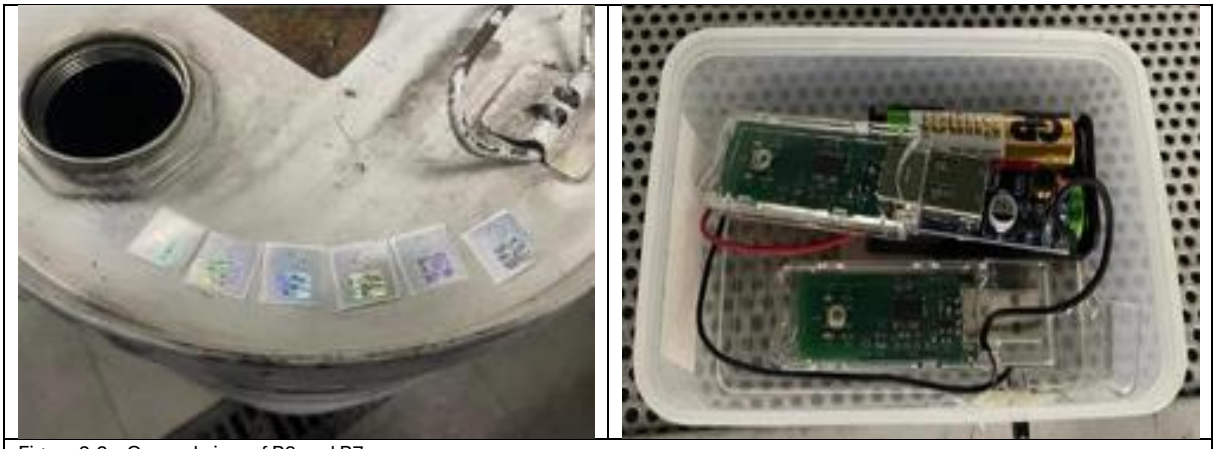

Figure 2.2 – General view of R3 and R7

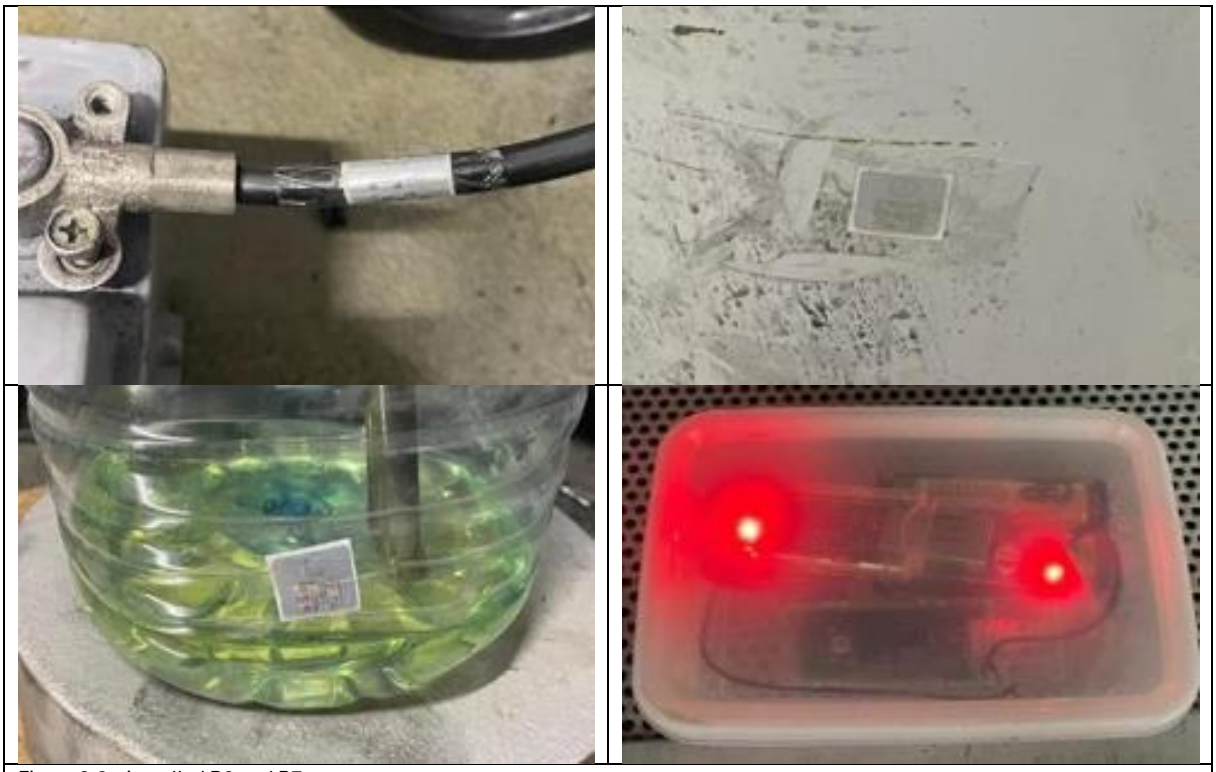

Figure 2.3 – installed R3 and R7

The ESC of the engine with the R3 and R7 installed was obtained. For more detailed data, see Appendix Table B1.

Fuel consumption and environmental parameters are shown in Tables 2.4 and 2.5

#	Parameter Name Mesurement	Units	Value							
			#1		#2		#1		#2	
1	Speed of rotation	min^{-1}	2497	2501	2493	2503	3502	3507	3496	3508
2	Throttle position	%	40	60	40	60	40	60	40	60
3	Power	HP	37.9	40.8	37.2	41.1	53.8	64.9	53.7	64.1
4	Power	KW	27.9	30.1	27.4	30.3	39.7	47.9	39.6	47.3
5	Torque	Nm	106.8	114.7	105.1	115.5	108.2	130.4	108.2	128.7
6	Fuel consumption (stand)	g/min	138.0	138.0	132.0	144.0	198.0	228.0	198.0	228.0
7	Specific fuel consumption	g/KWh	296.8	275.1	289.1	285.1	299.2	285.6	300.0	289.2

Table 2.4 – Determination of parameters in steady-state modes

#	Parameter Name	Units	Value			
1	Speed of rotation	min^{-1}	2510	2501	3503	3505
2	Throttle position	%	40	60	40	60
3	Power	HP	38.4	40.9	54.8	66.3
4	Power	KW	28.3	30.2	40.4	48.9
5	Torque	Nm	107.7	115.3	110.1	133.3
6	Fuel consumption (stand)	g/min	144.0	144.0	198.0	228.0
7	Fuel consumption (weight	g/min	115.0	117.0	168.0	183.0
8	Specific fuel consumption	g/KWh	243.8	232.5	249.5	224.5
9	CO	%	2.089	1.827	4.273	3.592
10	CO_2	%	13.93	14.26	12.90	13.42
11	CH	mln^{-1}	141.0	70.0	73.0	52.0
12	O_2	%	0.254	0.182	0.130	1.443
13	λ		0.949	0.954	0.889	0.962

Table 2.3 – Determination of fuel consumption and environmental parameters

Based on the results of the test, a summary analysis of the obtained parameter values was performed. A comparative ESC is shown in Figure 2.5

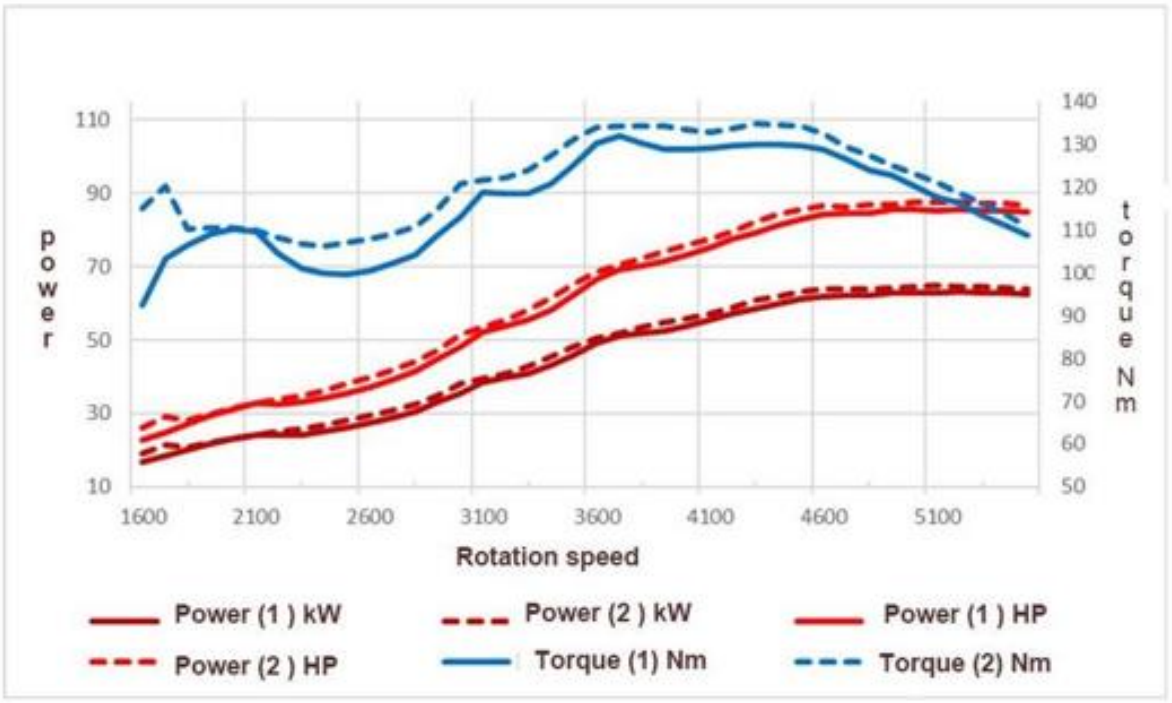

Figure 2.5 – Comparative ESC, where (1) is the base engine, (2) is the engine with the R3 and R7 installed

Table 2.6 shows comparative values at steady state.

#	Parameter Name Mesurement	Units	Basic engine				With R3 and R7			
1	Speed of rotation	min^{-1}	2570	2496	3500	3499	2510	2501	3503	3505
2	Throttle position	%	40	60	40	60	40	60	40	60
3	Power	KW	26.2	27.0	37.1	44.7	28.3	30.2	40.4	48.9
4	Fuel consumptein (weight)	g/min	118.0	133.0	171.0	207.0	115.0	117.0	168.0	183.0
5	Specific fuel consumption	g/KWh	269.8	295.8	276.2	277.6	243.8	232.5	249.5	224.5
6	**Reduction of fuel consumption**	**%**	-	-	-	-	**9.6**	**21.4**	**9.7**	**19.1**
7	CO	%	2.341	1.847	4.485	3.612	2.089	1.827	4.273	3.592
8	CO_2	%	14.56	14.79	14.35	14.43	13.93	14.26	12.90	13.42
9	CH	mln^{-1}	201.0	204.0	153.0	125.0	141.0	70.0	73.0	52.0
10	O_2	%	0.954	0.658	0.561	1.286	0.254	0.182	0.130	1.443
11	λ		1.058	1.042	1.031	1.026	0.949	0.954	0.889	0.962

Table 2.6 – shows comparative values at steady state

As a result of the analysis of the obtained data, we can note a significant decrease in specific fuel consumption in a number of modes (2500rmp and 3500rmp when the throttle is opened by 60%) which reached a value of 21.4%. It is also worth noting a slight improvement in environmental indicators.

In order to determine the engine operating modes that achieve the maximum and minimum effect from the influence of the R3 and R7, it is necessary to conduct a test cycle according to an extended program. These tests will allow to record the areas of the

engine operation modes and compare them with the main ones presented on the cyclograms of vehicle movement and the selection of optimal tests and operating conditions for conducting full-scale road tests.

Conclusion

As a result of testing the device R3 and R7 installed on the elements of the fuel system and electrical wiring of the test stand based on the V-21126 engine, results were obtained that confirmed the effectiveness of these devices and, as a result, an increase in the effective and improved environmental parameters of the engine. During the tests, it was revealed that there is a decrease in specific fuel consumption after the operation of the devices R3 and R7 for 6 days. The results of processing experimental data show that in the entire range of speed modes of the external speed characteristic, the average integral increase in poser was 4.2%, the increase in torque was 4.4%. At the n=2500 rpm mode, when the throttle was opened by 60%, the maximum reduction in fuel consumption reached values of 21.4% compared to the level of fuel consumption for the engine without the use of R3 and R7 devices. It should be noted that for a comprehensive assessment of the experimental data obtained and a deeper study of the result obtained in a wide range of engine operating modes, it is advisable to conduct additional studies aimed at determining the physics of the process, conducting engine indexing, evaluating a larger number of parameters of the tested engine (temperature and exhaust gas composition, local heat fluxes on the surface of the combustion chamber) and simulation of the workflow using modern methods of computational fluid dynamics to obtain a verified workflow model using the corresponding equations of chemical kinetics.

List of sources used

1. Superflow – SF-902. Engine test bench. Original Manual/Pub.No.:190322 Rev.: 1. April 2019
2. PM-03/2024-04

Appendix

Table A1- ESC of the base engine without R3, R7

Frequency of rotation, rpm	Power, kW	Power, HP	Torque, Nm
1700	16,7	22,7	92,4
1700	18.4	24.9	103,3
1800	20,1	27,2	106,4
1900	21,7	29,4	109,0
2000	23,1	31,3	110,3
2100	24,1	32,7	109,6
2200	24,1	32,6	104,4
2300	24,3	33	101,0
2400	25,1	34,1	100,0
2500	26,1	35,4	99,7
2600	27,4	37,1	100,5
2700	28,9	39,2	102,3
2800	30,6	41,5	104,3
2900	33,0	44,8	108,8
3000	35,5	48,1	112,9
3100	38,6	52,3	118,8
3200	39,7	53,8	118.4
3300	40,9	55,5	118,5
3400	43,0	58,3	120,8
3500	45,8	62,1	125,0
3600	49,1	66,6	130,3
3700	51,1	69,3	131,9
3800	51,9	70,3	130,3
3900	52,6	71,4	128.8
4000	53,9	73,1	128,7
4100	55,5	75,2	129,2
4200	57,1	77,4	129,7
4300	58,5	79,3	129,8
4400	59.9	81,2	129,9
4500	61,1	82,8	129,6
4600	62,0	84,1	128,7
4700	62,3	84,5	126,6
4800	62,3	84,5	124,0
4900	63,0	85,4	122.7
5000	63,0	85,4	120,3
5100	62,9	85,3	117,7
5200	63,2	85,7	116,1
5300	62,9	85,3	113.4
5400	62,8	85,1	111,0
5500	62.6	84,9	108,7

Table B1-ESC of the engine with R3, R7

Frequency of rotation, rpm	Power, kW	Power, HP	Torque, Nm
1700	19,3	26,1	115,0
1700	21,4	29,0	120,3
1800	20.8	28.2	110,2
1900	22,0	29,8	110,5
2000	23,1	31.4	110,5
2100	24,2	32,8	109.8
2200	25,0	33,8	108,3
2300	25,7	34,9	106,7
2400	26,7	36,2	106,3
2500	28,0	38,0	106,9
2600	29,4	39.8	107,8
2700	30,8	41.8	109,0
2800	32,5	44.1	110,8
2900	34,8	47,2	114,7
3000	38,0	51,5	120,8
3100	39,5	53,6	121,7
3200	40,9	55,5	122,1
3300	42,8	58,1	124,0
3400	45,4	61,5	127,4
3500	48,1	65,2	131.2
3600	50,4	68,4	133.8
3700	52,0	70,5	134,2
3800	53,4	72,3	134,1
3900	54,8	74,3	134,2
4000	55,9	75,8	133, 4
4100	57,1	77,4	132,9
4200	58,8	79,7	133,7
4300	60,7	82,2	134,7
4400	62,0	84,1	134.6
4500	63,2	85,7	134,2
4600	63,8	86,5	132.4
4700	63,7	86,3	129,4
4800	64,0	86.8	127,3
4900	64,2	87,0	125,0
5000	64,4	87.4	123,1
5100	64,7	87,7	121,1
5200	64,5	87,5	118,5
5300	64,4	87,3	116,1
5400	64,2	87,1	113.6
5500	63,8	86,6	110,8

Test results – Power and Torque