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SELECTION OF TURBOCHARGER FOR THE T3.251 ENGINE

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Abstract

In this research, a selection of turbocharger for atmospheric engine with automatic ignition T3.251 is described. This experimental engine was designed for driving small tractors. The purpose of turbocharging was to achieve a power of 45 kW. This atmospheric engine at 2250 rpm had power of 35 kW. In the first phase, the initial calculations of the turbocharger parameters were made according to the method proposed be Garret Company. The B65 turbocharger was selected for the study with flue gas exhaust in a multi-variant combination of turbines and compressors. Modifications were made to both turbine and compressor bodies as well as the size of their rotors. Altogether, eleven variants of the B-65 turbocharger were studied. The B65 turbochargers were fitted with an adjustable exhaust valve. By changing the spring preload, the supercharging pressure was adjusted. The research was carried out by performing the external characteristics and load characteristics of the engine under the same operating conditions and settings of the engine and injection equipment. The article presents the co-operation lines of an engine and superchargers using the characteristics of the discussed earlier compressors at Institute of Aviation. The effects of different turbocharger configurations on engine performance, power, fuel consumption, temperature and smoke emissions were also analysed. An analysis of the correct selection of turbochargers was performed.

Keywords: *transport, self-ignition engine, turbocharging*

1. Introduction

The turbocharger's choice is to combine the turbocharger with engine to achieve the target. The most common is to increase engine power, improve efficiency, and reduce the toxicity of exhaust gases [1, 2 3, 4, 6, 7]. The pre-selection procedure of the turbocharger is described on the turbocharger manufacturer's websites. In this research was used Garrett's method [8]. The baseline was an atmospheric AD3.152 engine with the following data:

– V_{SS} = 2.502 dm^3,
– N_e = 34.6 kW / 2250 rpm,
– ε = 16.5 (compression ratio),
– g_e = 250 g/kWh.

As the result of supercharging, we want to raise the power to 45 kW. First, we calculate the mass flow rate:

$$Q_p = N_e \cdot A/F \cdot g_e/60\,, \tag{1}$$

where:
N_e – power engine,
A/F – air-fuel ratio,
g_e – specific fuel consumption.

For the calculated expenditure, the inlet manifold pressure was calculated to supply the required air quantity to the engine to obtain the desired power:

$$P_d = \frac{Q_p \cdot R \cdot (273 + T_d)}{\eta_v \cdot n/2 \cdot V_{SS}}\,, \tag{2}$$

where:
R – constant gaseous air,
T_d – air temperature in inlet manifold,
η_v – volumetric efficiency,
n – engine speed.

2. Calculations

Tab. 1. Calculations of supercharging parameters

Description	Symbol	Value	Unit
Data			
Engine cylinder capacity	V_{SS}	2.5	dm^3
Maximum power speed	n	2250	rpm
Specific fuel consumption	g_e	245	g/kWh
Air-fuel ratio	A/F	22	–
Constant gas for air	R	287	J/kgK
Volumetric efficiency	η_v	98	%
Power engine	N_e	45	kW
Intake air temperature	T_d	55	°C
Atmospheric pressure	P_{atm}	101.33	kPa
Pressure losses behind the compressor	p2_strat	13.78	kPa
Pressure losses before the compressor	p1_strat	6.89	kPa
Calculation			
Mass flow of air	Q_p	0.07	kg/s
Absolute pressure behind the compressor	P2_abs	137.77	kPa
Absolute pressure behind the compressor with losses	P2_abs	151.55	kPa
Compressor compression	PIsc	1.60	–

To obtain the assumed engine power, we should select a compressor with an airflow rate greater than 0.07 kg/s and a compression ratio above 1.6 for rated conditions.

For the T3.251 engine, the throughput lines were set at 1100 and 2250 rpm, as shown in Fig. 1.

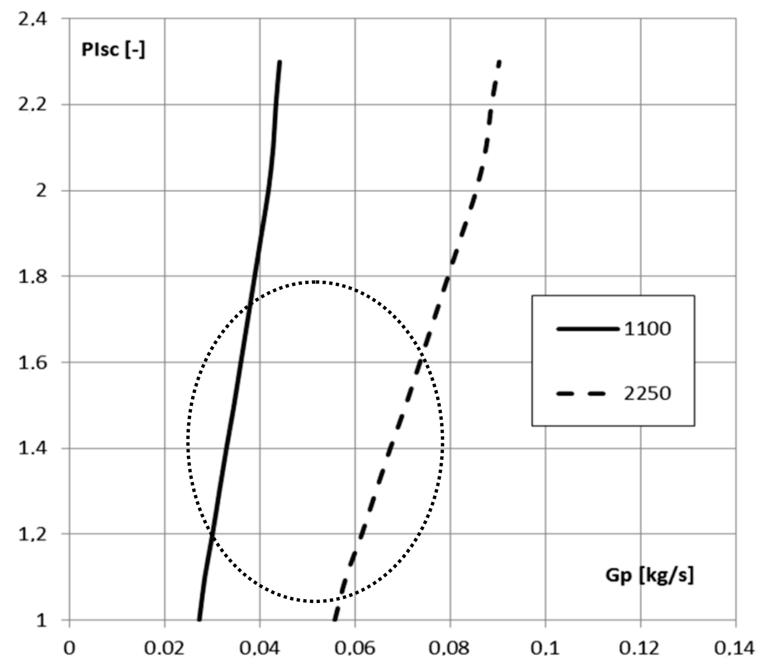

Fig. 1. T3.251 engine throughput lines with the optimum engine co-operation field with the selected compressor

B65 compressors with adjustable exhaust vent were used. By increasing the spring tension in the relief exhaust valve, the boost pressure was increased. This allowed us to match the compressor characteristics to the engine parameters. The higher number at the end of complementation indicated higher valve spring tension and higher boost pressure.

The following designations of SX-TY-ZZ.1-7 complementation was taken: SX – compressor designation, TY – turbine designation, ZZ – designation of the turbine enclosures, „1-7” – regulating the adjustable exhaust vent.

Designations of rotors and turbine enclosures were taken as follows [5]:

Tab. 2. Designations of rotors and turbine

Compressor		Turbine		
Compressor designation	Rotor diameter [mm]	Turbine designation	Rotor diameter [mm]	Turbine enclosures factory designation
S1	34	T3	47	3.31
				4.46
		T4	52.5	3.31
S4	39.4			4.46
		T1	62	3.22
				4.33

Set S1-T3-3.31-„0” indicates a 34 mm rotor compressor, a turbine with a 47 mm rotor and an enclosure of 3.31 with a 34 mm rotor compressor without pre-spring pressure relief valve spring.

3. Research results

The study was conducted for the selected turbine-compressor assembly for various adjustable exhaust vent settings. The tests were performed on a braking station equipped with a Schenck electronic power brake and AVL fuel consumption scales [9]. The compressor characteristics have been mapped with the engine. Assembly comparisons have been presented for better visualization of changes in turbocharger co-operation.

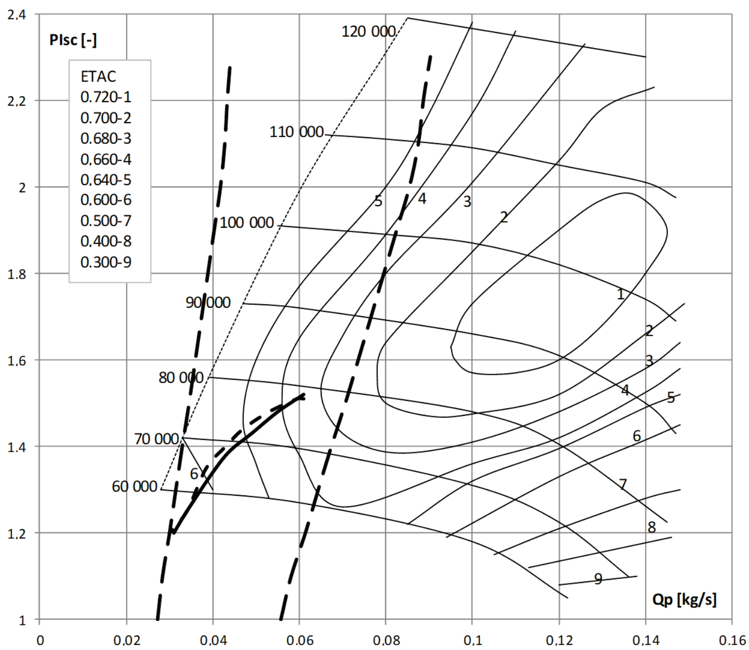

Fig. 2. Engine cooperation lines with turbochargers: —— S4-T4-4.46-„0”, ---- S4-T4-3.36-„0” (ETAC – compressor efficiency)

Tab. 3. Engine operation parameters with compressor S4

N [rpm]	Parameter	Unit	S4-T4-4.46-„0”	S4-T4-3.36-„0”
2250	N_e	kW	43.4	43.0
	g_e	g/kWh	239.1	239.5
	T_{pt}	°C	625	640
	D	°B	3.35	3.2
1600	N_e	kW	33.4	33.2
	g_e	g/kWh	237.8	238.6
	T_{pt}	°C	610	620
	D	°B	4.5	4.4
1000	N_e	kW	20.1	19.9
	g_e	g/kWh	244.1	244.1
	T_{pt}	°C	540	535
	D	°B	5.4	5.3

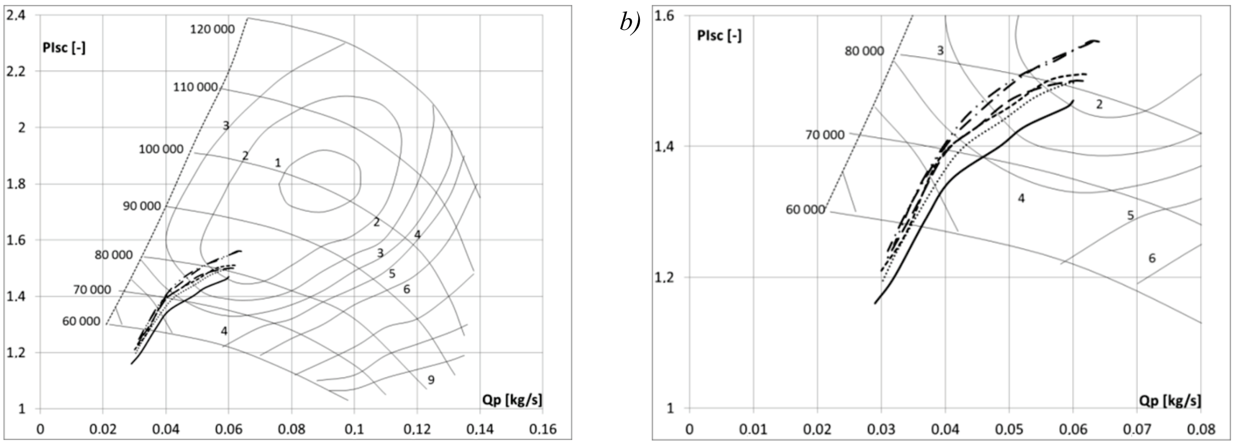

Fig. 3. Engine cooperation lines with turbochargers: ——— S1-T1-4.33-„0”, ···· S1-T1-3.22-„0”, --- S1-T4-4.46-„0”, − — S1-T4-3.31-„0”, ·-·-·S1-T3-4.46-„0”,-··-··S1-T3-3,31-„0”, a) whole area, b) the enlargement of selected interval

Tab. 4. Engine parameters with tested compressors

n [rpm]	Parameter/ /Unit		S4-T4- -4.46	S4-T4- -3.31	S1-T1- -4.33	S1-T1- -3.22	S1-T4- -4.46	S1-T4- -3.31	**S1-T3- -4.46**	S1-T3- -3.31
2250	N_e	kW	43.4	43.0	42.5	41.4	43.9	43.4	**44.5**	43.7
	g_e	g/kWh	239.1	239.5	240.9	246.7	235.8	237.2	**233.8**	235.2
	T_{pt}	°C	625	640	630	640	615	630	**615**	620
	P_{pt}	kPa	56.9	73.6	58.9	86.3	59.8	73.6	**62.8**	71.6
	P_{zs}	kPa	51.0	49.1	45.1	48.1	50.0	49.1	**54.0**	54.0
	D	°B	3.35	3.2	3.25	3.4	3.0	3.1	**2.6**	2.35
1600	N_e	kW	33.4	33.2	33.2	32.5	34.2	33.9	**34.5**	33.9
	g_e	g/kWh	237.8	238.6	238.6	242.6	231.2	234.0	**232.9**	233.1
	T_{pt}	°C	610	620	605	615	615	605	**600**	590
	P_{pt}	kPa	41.2	54.0	41.2	67.7	40.2	53.0	**44.1**	54.0
	P_{zs}	kPa	38.3	39.2	35.3	39.2	42.2	42.2	**44.41**	45.1
	D	°B	4.5	4.4	4.7	4.4	4.4	4.5	**4.0**	4.0
1000	N_e	kW	20.1	19.9	19.4	19.6	20.2	20.4	**20.3**	20.1
	g_e	g/kWh	244.1	244.1	250.3	247.8	239.5	235.2	**241.5**	241.9
	T_{pt}	°C	540	535	530	540	525	580	**540**	530
	P_{pt}	kPa	17.7	23.5	24.5	29.4	19.6	34.3	**20.6**	25.5
	P_{zs}	kPa	19.6	19.6	15.7	18.6	20.6	29.4	**23.5**	24.5
	D	°B	5.4	5.3	5.8	5.8	5.0	5.1	**5.3**	5.0

The S1-T3-4.46 turbocharger with the T3.251 engine achieved the best performance that is why it was taken for further research. This setup reached the lowest fuel consumption, smallest smoke exhaust gas, lowest exhaust gas temperature. In this complementation, the pressure control study was carried out.

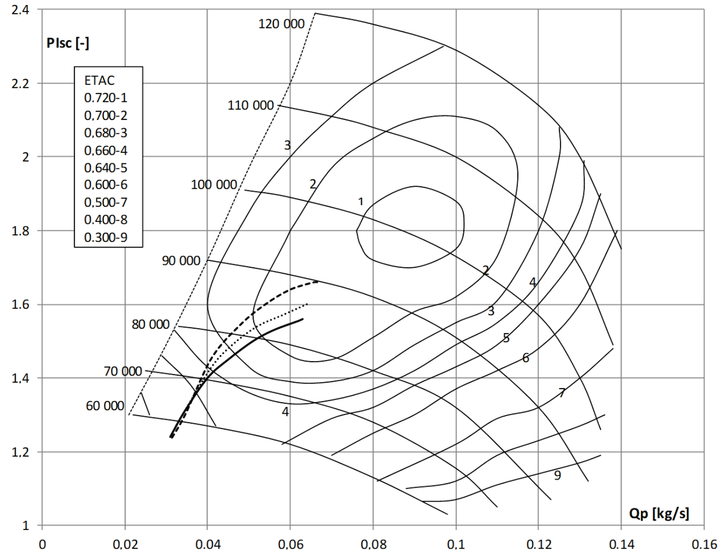

Fig. 4. Engine cooperation lines with turbochargers: —— S1-T3-4.46-„0”,···· S1-T3-4.46-„2,7”,----S1-T3-4.46-„5”

Tab. 5. Engine parameters with tested compressors

n [rpm]	Parameter/Unit		S1-T3-4.46-„0”	S1-T3-4.46-„2.7”	S1-T3-4.46-„5”
2250	N_e	kW	44.5	44.7	44.8
	g_e	g/kWh	233.8	231.5	229.0
	T_{pt}	°C	615	600	590
	P_{pt}	kPa	62.8	65.7	73.6
	P_{zs}	kPa	54.0	58.9	68.0
	D	°B	2.6	2.2	2.1
1600	N_e	kW	34.5	34.8	35.0
	g_e	g/kWh	232.9	227.0	227.5
	T_{pt}	°C	600	580	570
	P_{pt}	kPa	44.1	48.1	51.0
	P_{zs}	kPa	44.41	48.1	53.0
	D	°B	4.0	4.0	3.8
1000	N_e	kW	20.3	20.2	20.2
	g_e	g/kWh	241.5	241.9	241.5
	T_{pt}	°C	540	525	530
	P_{pt}	kPa	20.6	20.6	20.6
	P_{zs}	kPa	23.5	23.5	22.6
	D	°B	5.3	5.2	5.1

Figure 5 shows the lines of co-operation of the engine (external and load characteristics for 2250, 1400, 1000 rpm) with the most preferred variant of the turbocharger S1-T3-4.46-5.

4. Conclusions

1. The tests show that the turbochargers were oversized to the T3.251 engine. The fields of highest efficiency of both compressors were in compression 1.8 and the airflow rate of 0.8-1 kg/s. The working area of the engine included airflow rates of 0.25 to 0.65 kg/s.

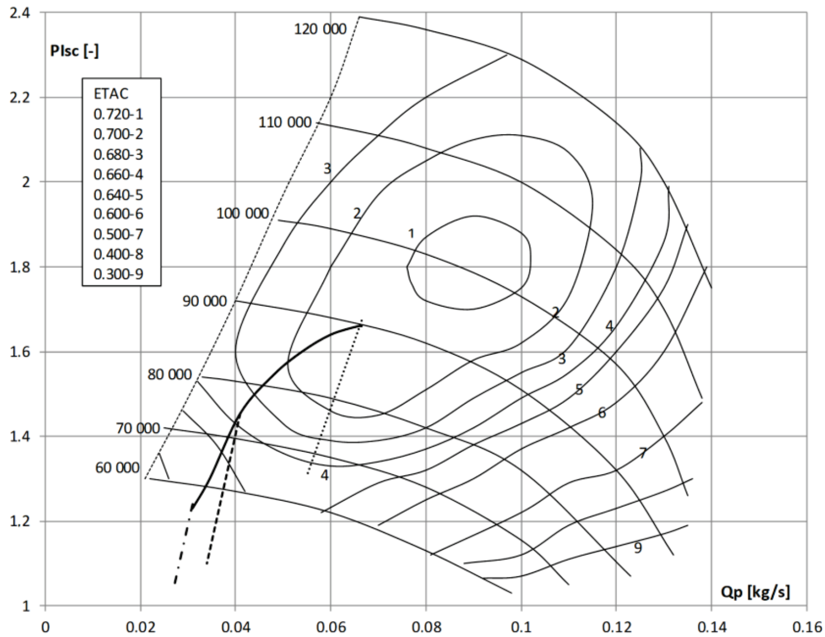

Fig. 5. Engine cooperation lines with turbochargers S1-T3- 4.46-„5”: ···· 2250,----1400, -·-·1000

2. The S4 compressor engine worked close to the pumping limit.
3. The tightening of the turbine enclosure did not cause any significant changes in the compressor co-operation with the engine.
4. The situation was improved (about 8% on average) by increasing the supercharging pressure. Co-operation lines were performed in areas with higher compressor efficiency. Even then, the desired area of cooperation included low compressor speeds and efficiency of less than 65%.
5. Increasing the boost pressure (higher spring tension in the valve) resulted in a decrease in exhaust gas temperature and a decrease smokiness.

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