"We started our new designs and we performed the whole turbocharger simulations, obtained the thermal distributions and found material substitution opportunities. We achieved this with FloEFD

Mert Alpaya, Researcher, Borusan R&D

This article was originally published in Engineering Edge Vol. 7 Iss. 1

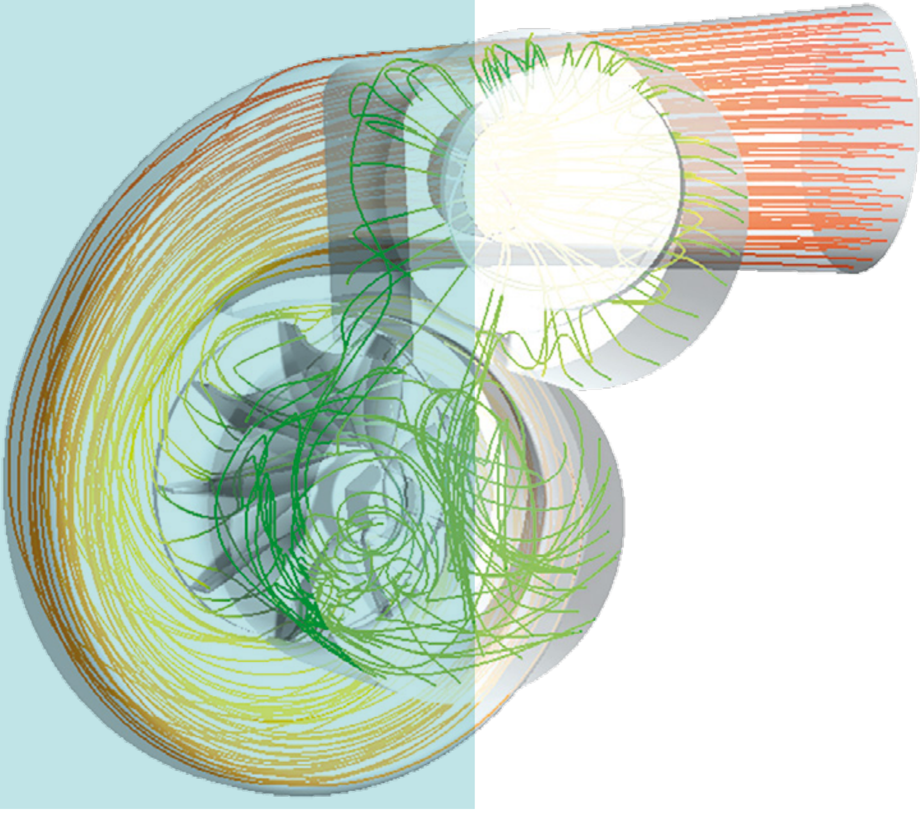
New Development of a Turbocharger with FloEFD

By Mert Alpaya, Borusan R&D

Borusan R&D is responsible for developing R&D strategies and conducting R&D studies for the entire Borusan Group, which comprises the Steel, Logistics, Energy, Automotive and Distributorship divisions. The automotive division, Supsan, produces engine components for the OEM and after sales market. Supsan is the largest manufacturer of engine valves in Turkey and distributes turbochargers, among others. Supsan and Borusan R&D started a collaborative project with the goal of developing and manufacturing completely new turbochargers.

The turbocharger is a small, complex and critical component of the vehicle because it directly determines the engine performance. A turbocharger consists of two different types of turbomachines, a turbine and a compressor, which are combined in one single component. Multiple design studies must be carried out for the design: an analysis of the flow conditions and heat distribution, as well as bearing design and lubrication. The high temperature of the exhaust gases makes the design critical. The exhaust gas from the engine drives the impeller on the exhaust side, and with the common shaft the impeller at the cold air side is driven, which then sucks in and compresses the air on the air intake side. The compressed air increases the combustion efficiency in the engine.

The turbocharger developed in this project is shown in Figure 1. It is designed for 1.5-litre engines in series vehicles. The rotational speed is controlled by a waste gate actuator.



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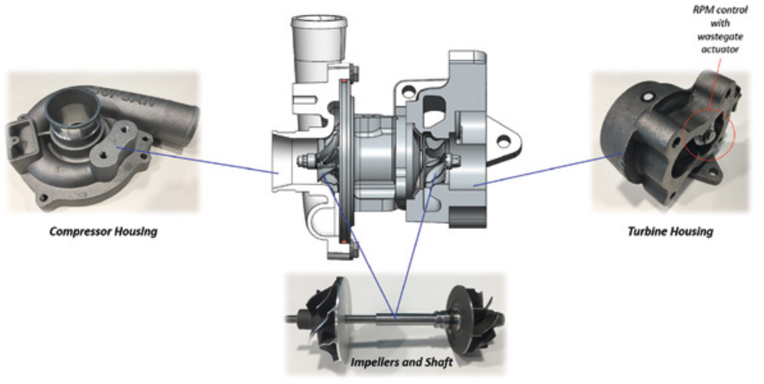


Figure 1. Turbocharger components

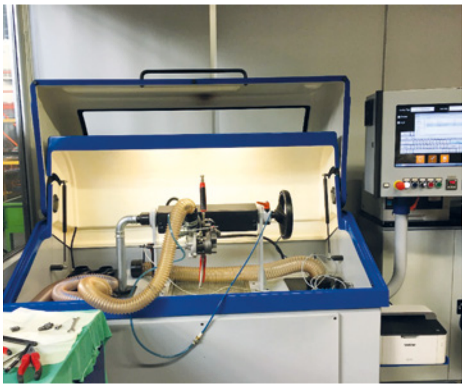


Figure 2. Test rig

The turbocharger was tested on the test rig shown in Figure 2. The turbine inlet pressure has been changed to modify the rotational speed. The flow rate and the pressure were measured. Twelve different test cases were measured on the test rig and later compared with the simulation results.

The CAD model for the compressor side is shown in Figure 3. A fictional body was used to define the rotating area, the boundary conditions were mass flow at the inlet and total pressure at the outlet.

For the turbine side, two different cases were investigated in which the wastegate lid was opened and closed, for different rotational speeds (Figure 4). A total inlet pressure and an environmental pressure for the outlet were applied.

Six loading conditions were investigated for both sides, as shown in Figure 5.

The deviation from the test results is between 2% and 7%, depending on the impeller rotational speed. The results for the six cases are shown in Figure 7.

The results for the waste gas side with closed and opened wastegate are shown in Figure 8. Three different cases were simulated for both positions. The deviation from the test results is a maximum of 9.4 %.

Following the comparison and the confidence in the simulation based on good agreement, further simulations were quickly conducted with FloEFD. The entire turbocharger, including the hot turbine gases and oil flow, was simulated (Figure 9). The temperature distribution on the entire component and especially for the shaft region was analyzed (Figure 10). Different impeller materials and their effects on the shaft temperature distribution were investigated (Figure 11). After that, the thermal expansions and the clearances for the operating conditions were calculated.

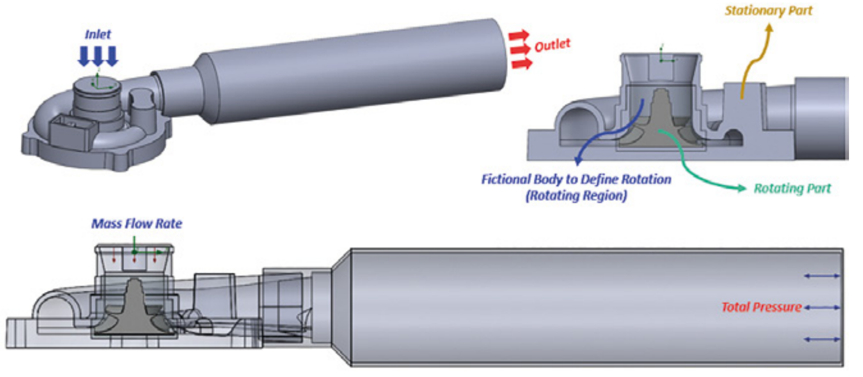


Figure 3. CAD model compressor side

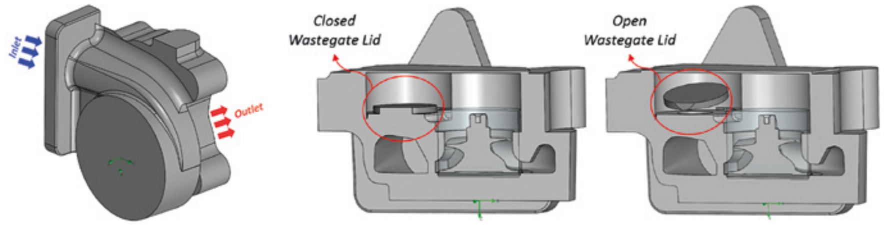


Figure 4. CAD model turbine side

Case	Rotational Speed [rpm]	Inlet Mass Flow Rate [kg/s]	Outlet Total Pressure [Pa]
1	51.670	0,03222	108.222
2	64.753	0,04270	114.138
3	86.010	0,06236	122.298
4	88.217	0,06704	127.398
5	101.050	0,08087	131.682
6	104.953	0,08778	136.884

Boundary Conditions for Compressor

Case	Rotational Speed [rpm]	Inlet Total Pressure [Pa]	Outlet Pressure [Pa]	
1	24.550	111.486	101.325	Wastegate is open
2	44.360	121.133	101.325	
3	57.120	130.652	101.325	
1	26.270	111.398	101.325	Wastegate is closed
2	47.370	121.276	101.325	
3	63.090	131.656	101.325	

Boundary Conditions for Turbine

Figure 5. Six loading conditions

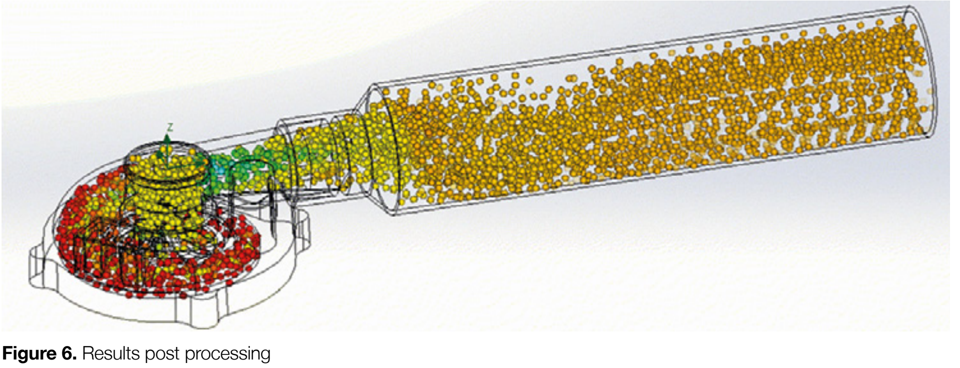


Figure 6. Results post processing

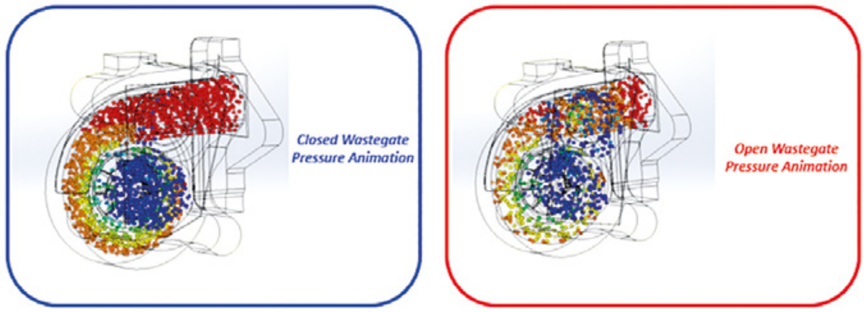
	Case	Test Results [m³/s]	FloEFD Results [m³/s]	Deviation [%]
1	51.670 rpm PR = 1,061	0,02520	0,02550	1,19
2	64.753 rpm PR = 1,119	0,03167	0,03240	2,31
3	86.010 rpm PR = 1,199	0,04316	0,04520	4,73
4	88.217 rpm PR = 1,249	0,04454	0,04680	5,07
5	101.050 rpm PR = 1,291	0,05199	0,05550	6,75
6	104.953 rpm PR = 1,342	0,05428	0,05830	7,41

Figure 7. Results for six cases

A comparison of the initial impeller material and the four alternatives is shown in Figure 12.

The shaft and impeller surface temperatures were exported to MATLAB and the thermal expansions and clearances were calculated. For the alternatives, the differences of the clearances between the bearings, shaft and housing were analyzed. These investigations led to the selection of the appropriate material, which also enabled cost optimizations.

The Borusan R&D engineers developed completely new turbochargers for a series of vehicles. The thermal distributions were determined with the use of FloEFD in the simulation process. The new designs were optimized on the basis of the analyses and the resulting expansions and clearances.



	Case	Test Results [kg/s]	FloEFD Results [kg/s]	Deviation [%]
1	26.270 rpm	0,01839	0,01695	-7,83
2	47.370 rpm	0,02592	0,02460	-5,08
3	63.090 rpm	0,03253	0,02946	-9,44

	Case	Test Results [kg/s]	FloEFD Results [kg/s]	Deviation [%]
1	24.550 rpm	0,03194	0,02950	-7,65
2	44.360 rpm	0,04550	0,04240	-6,81
3	57.120 rpm	0,05642	0,05280	-6,41

Figure 8. Results waste gas side

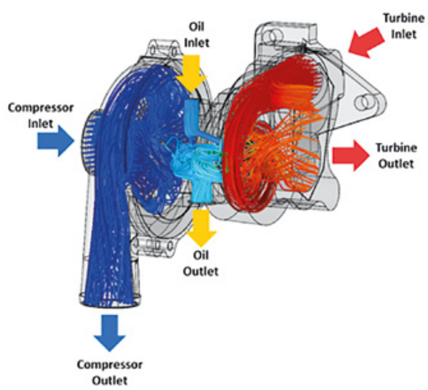


Figure 9. Simulation of the entire turbocharger

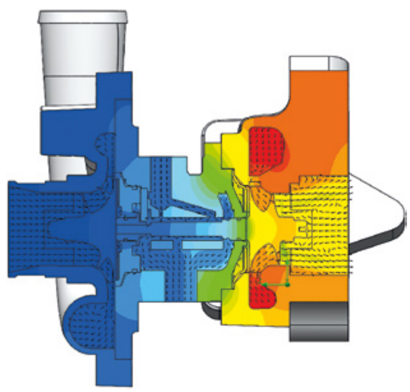


Figure 10. Temperature distribution

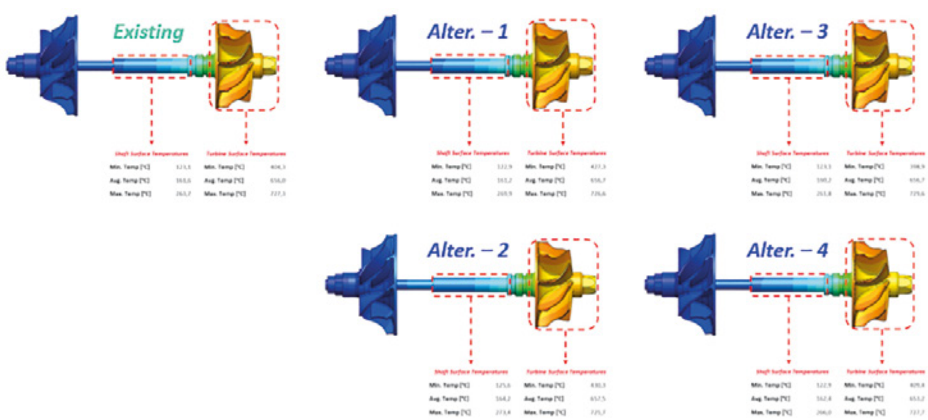


Figure 11. Investigation of different impeller materials

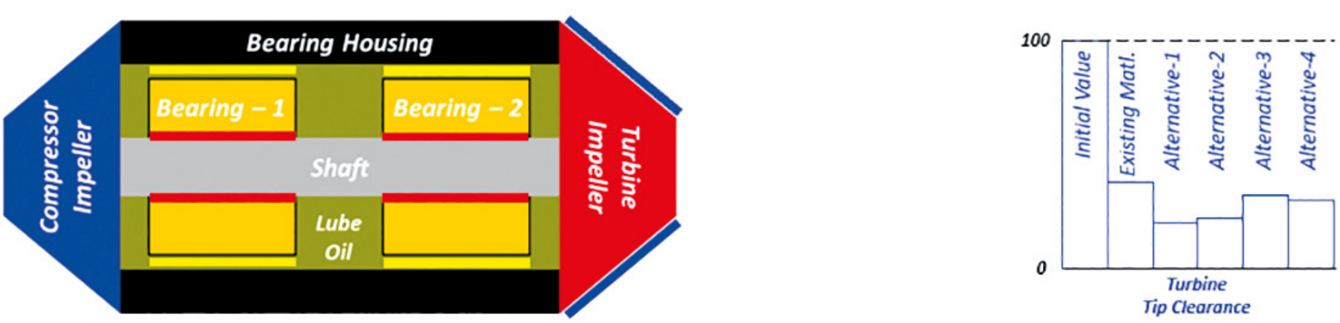


Figure 12. Comparison of thermal expansions and clearances

This article was originally published in Engineering Edge Vol. 7 Iss. 1

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