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Providing Eligibility Criteria On Turbocharger Filter Silencer Design Processes

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HIGHLIGHTS

- Complete covering with sound absorptive material doesn't mean good sound attenuation.
- Filtration filter element thickness on turbochargers should be kept as minimum as needed.
- Atmospheric pressure conditions directly affects diesel engine performance.

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ABSTRACT

Supply of ventilation air to either the engine room or diesel engine directly affects engine performances. Main criteria is supply of air volume and pressure into the cylinder. When Air starts to come until the cylinders, there many points which behave as restrictions. These are ventilation grills. ventilation fans, ventilation casings, misteliminators, manual or pneumatically adjusted fan dampers, number of bending of ventilation casing, cleanness of casings, air flow speed, air filters, turbocharger filter and silencers, engine's scavenge air cooler restrictions. Here, we focused on optimum required air need through turbocharger for local diesel engine. While researching actual need, new turbocharger filter were designed and manufactured for engine manufacturer.

Introduction

Diesel engine performances may vary from many different variations which affect and change both efficiency and emissions results. One of the main issues are supplied ambient air pressure and turbocharger related restrictions. In this topic, New design turbocharger filter with silencer factory test results for local manufactured TULOMSAŞ brand TLM 16PA4-185 type diesel engines which is manufactured under Semt Pielstick license, and expected results were considered for new building ferries which will be used at Lake Van.

Two-stroke or four-stroke diesel engines have high efficient turbochargers in order to get more power. Today's technology brings diesel engine manufacturers to obtain highest productivity from fossil based fuels. Thus, competitive engines take bigger piece on market worldwide. Market trends and new research and developments improve low fuel consumptions per kW/Hp produced so It let us to release lowest emission rates. There are also other factors which affect total efficiency on ships. Long term researches and operational experiences created a new approach to shipping industry. Energy

Efficiency Design Index (EEDI) is just one of the last decade of future mandatory requirement of International Maritime Organization (IMO).

NOx and PM are the emission components of most concern from diesel engines. Although the air/fuel ratio in a diesel cylinder is very lean, the air and fuel are nota homogeneous charge as in a gasoline engine. As the fuel is injected, the combustion takes place at the flame-front where the air/fuel ratio is near stoichiometry. At localized areas, or in cases where light-ends have vaporized and burned, molecules of carbon remain when temperatures and pressures in the cylinder become too low to sustain combustion as the piston reaches bottom dead center. Therefore, these heavy products of incomplete combustion are exhausted as PM. EPA believes that the new emission standards for marine diesel engines can be met using technology that has been developed for and used on locomotive, land-based non-road, and highway engines. [EPA]

False design and products cause incomplete burning on diesel engine.Turbocharger selection and its filters are main compenents of air intake system of any brand diesel engine. Both components have great impact on efficient combustion results. Turbocharger maximum or optimum efficiency can be achieved by the very accurate coordination of turbocharger and diesel characteristics during design and engine test stages. Engine manufacturers are named their Maximum Continous Ratings as MCR. Duration of MCR at peak loads may vary from one to another manufacturer's decision. Maximum allowable duration changes according to engine manfacturer but, these requirements finally decided by buyer's recommendation such as light duty and heavy duty engines. On the other hand, it is also well known that marine diesel engines are operated on lower loads than maximum design MCR loads. Based on practical experience, we can conclude that propulsion marine engines are generally operated between 75% -85% and auxiliary engines operated between 50% -75% of their MCR. These loads for auxiliary engines may even lower than stated values since there are random started and stoped consumers on board a vessel.

Material and methodology

On application methodology, existing engine specifications and air requirements, turbocharger requirements and restrictions, barometric effects because of sea level altitude(elevation), engine room ISO 3046-1:2002(E) and ISO 15550:2002(E) reference requirements, International Association of Classification Societies (IACS) rule M28 and atmospheric conditions defined by CIMAC were main topics which should be considered and analyzed.

Engine Technical Fundamentals Characteristics

Cycle: 4 stroke - single acting
Number of cylinders: 16
Arrangement: Vee - form at 90º
Maximum Continuous power rating : 1770 kW (2400 metric HP)
Cylinder bore: 185 mm
Piston stroke: 210 mm
Swept volume (per cylinder): 5.65 L
Compression ratio : 13.5/1
Mean piston speed : 10.5m/ sec (at 1500rpm)

Figure.1 *Cross Section of PA4-185 diesel engine.*

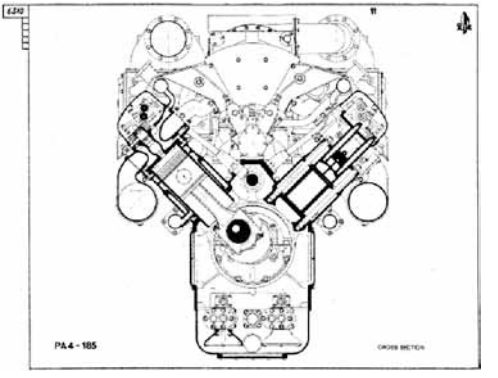
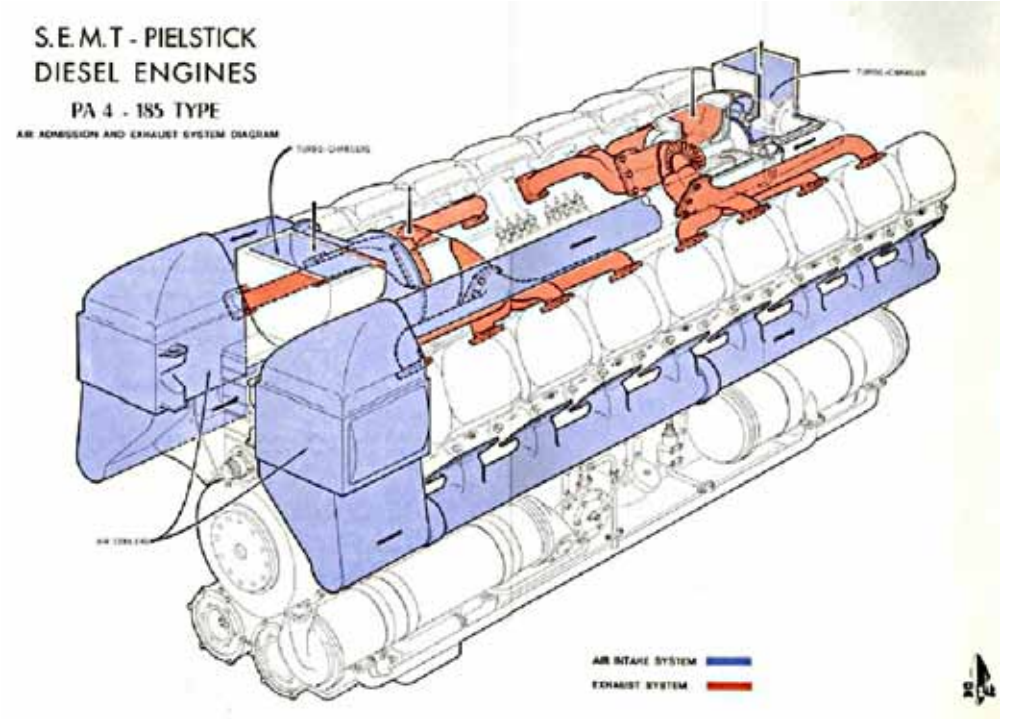


Figure.2 *Air admission and exhaust system diagrams of PA4-185 diesel engine.[Semt Pielstick].*



Air and Gas Characteristics
Number of supercharger: 2 turbo-chargers
Type of supercharger: BBC VTR 250 or HS 400
Weigh of intake air (per hour): 12 930 kg
Maximum pressure loss at turbocharger air-inlet: 20 millibars
Charge air pressure: 1.4 bar (1,43 kg/cm²)
Weigh of exhaust gas (per hour): 13 340 kg
Cylinder head exhaust gas outlet temp.: 490ºC
Turbine inlet exhaust gas temp.: 590 ºC
Turbine inlet exhaust outlet temp.: 520 ºC
Gas pressure at turbine inlet: 0.87 bar (0.89 kg/cm²)

Reference atmospheric conditions are these defined by CIMAC
Ambient temperature: 20 ºC (68 ºF)
Atmospheric pressure: 981 mb (29 inches of mercury)
Relative humidity: 0.6
Water temperature at air –cooler inlet: 20 ºC (68 ºF)

International Association of Classification Societies (IACS) rule M28. [IACS rules M28].
Barometric pressure: 1,000 mbar
Air temperature: 45 ºC
Seawater temperature: 32 ºC
Relative air humidity: 60 %

ISO 3046-1:2002(E) and ISO 15550:2002(E) ISO ambient reference conditions/requirements
Barometric pressure: 1,000mbar
Turbocharger Air intake temperature: 25 ºC
Charge air coolant temperature: 25 ºC
Relative air humidity: 30 %

Although Lake Van is situated at an altitude of 1,640 m (5,380 ft) with harsh winters, it does not freeze due to its high salinity except

occasionally the shallow northern section. The lake water is strongly alkaline (pH 9.7–9.8) and rich in sodium carbonate and other salts, which are extracted by evaporation and used as detergents. Lake Van is situated in the highest and largest region of Turkey, which has a harsh continental climate. Average temperatures in July are between 22 and 25 °C, and in January between −3 °C to −12 °C. In particularly cold winter nights the temperature reaches −30 °C. Lake Van mitigates the climate somewhat, so in the city of Van, on the shore of the lake, the average temperature in July is 22.5 °C, and in January −3.5 °C. [Lake Van, Wikipedia]

Altitude of 1,640 m creates pressure change at this level. Pressure is generally increase with higher altitudes and increase quickly to sea level. If we climb upper hills, weight of air on our body is lowered. Pressure increases at lower levels rapidly. This is result of increase of different gases at lower levels. If we collect all gases in a closed column, total pressure of column will increase in conjunction with weigh of gases will increase.

Most important factor of pressure variation with altitude is temperature. Pressure at sea level is 1 Atmosphere=1.01325 bar and equivalent to =1013.25 milibar (mb) =101326 Pascal=1013.25 hectopascal(hPa) =29.92 in.Hg=760mm Hg=14.7 Lb/inch. Existing gases in atmosphere and their percentages are in below Table.3

Heating up of earth and air that close to ground level depend on sun radiation. That's why; warm air is placed to ground level. Temperature variation with altitude change is identified as "lapse rate". Lapse rate at troposphere is generally -6.5 °C/km. Lapse rate at dry air is -9.8 °C/km. As result, pressure will be dramatically different at 1,640 m.

Conceptional design was carried out and final prototype products were manufactured under these information and restrictions above. Turbocharger provider Huispano Suiza supplies to locomotive industry in common. Since there is no available place on engine for vertical installation of turbo silencer and filter. Requirement was forced us to pass beyond standard designs. On the other hand, there was no available filter unit for their marine type diesel engine. Some modification by Tulomsaş made it harder to provide suitable solution. As an initial preliminary design concept shown at figure.4, it had been though there had to many guiding fixed plates in order to guide the air which comes to filter horizontally. Main aim was to create a Vortex. Thus, air will gain enough speed while accessing to turbocharger. When

Gases in atmosphere

Gas Name	Symbol/Chemical Formula	% Volume at Dry Air
Nitrogen	N2	78,08
Oxygen	O2	20,95
Water	H2O	0 to 4%
Argon	Ar	0,93
Neon	Ne	0.0018
Helium	He	0.0005
Methane	CH4	0.00017
Hydrogen	H2	0.00005
Nitrous Oxide	N2O	0.00003
Ozone	O3	0.000004

Table.3 *Average composition of the atmosphere up to an altitude of 25 km.[www.physicalgeography.net]*

noise reduction criteria comes into the force. It was thought all surfaces must be covered with sound absorptive material. In actual prototype units shown at figure.6, it was seem that application didn't let us to give enough access area. Narrowing access area will reduce air quantity supplied to the turbocharger. As of above restrictions, number of fixed plates was reduced.

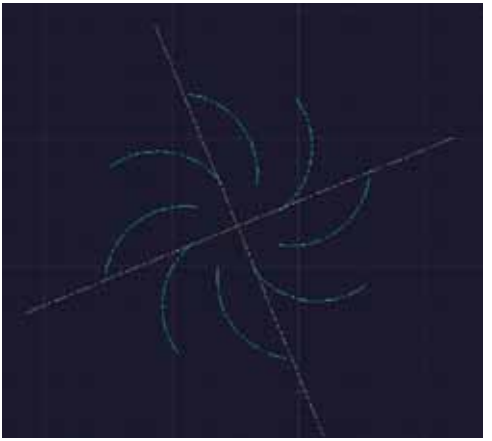


Figure.4 *Vortex design fixed guide plates.*

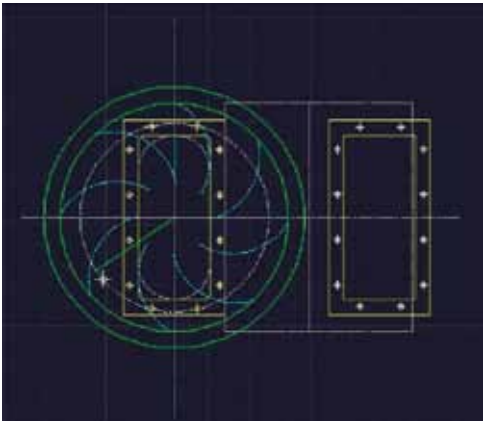


Figure.5 *Priliminary turbocharger filter design.*

Even design was completed; another restriction came into the force. Customer didn't expect they will get 75kg in total including sound absorptive materials. There was also no guarantee all these weights could be carried by turbocharger construction itself. Aluminum structure as main frame was decided to lower weigh. There were also a lot of difficulties while manufacturing at least 2 prototype units. Aluminum is not good material for processing. High pressure water jetting was used in order to get smooth corners and surfaces. Another problem was welding procedure during manufacturing. It required pre-heating for avoiding structural deformations.

Figure.6 *Vortex design prototype product.*

Figure.7 *Turbocharger outer filter prototype product.*

Distance pieces were designed and manufactured for turbocharger filter housing seating. Units were used just for trials. Inside diameter of casing unit kept as same as original turbocharger suction flange. Distance units fixed with steel wire ropes in order to prevent vibrational movements.

At shop trials, one of the filters with silencer unit was fitted with sound absorptive material. Other was left naked with its construction only. Figure.10 show us test

Figure.8 *Manufactured distance units.*

Figure.9 *Distance unit with steel wire rope.*

installations on PA4-185 diesel engine. Thus It let us to measure difference at both filter units how absorptive material handle sound attenuation. It was observed that there is only limited 3-4dB. When filter unit inside filled with 40mm thickness in total has great influence at pressure drop. It was observed, there should not be more copper filters as secondary filtration for some particulars. It was increased both pressure drop and total weigh. At the same time, manufacturing costs increased partially.

First tests were carried under atmospheric pressure conditions. There was not forced pressure inside test workshop. It seemed that there serious pressure drop even at %25 load as shown at Table12. When maximum allowable pressure drop remembered is 20 milibar, It was a big disappointment for trials. Forced pressure is normally in engine rooms

Figure.10 *Shop trial tests at TULOMSAŞ factory.*

Figure.11 *Visual pressure drop measurement, U-manometer.*

are supplied by mechanical ventilation axial electrical motor fans. It seemed that unless there is no positive pressure inside engine room, turbocharger behaves as vacuum cleaner and tries to suck air. When vacuum conditions are created great pressure drops can exists with structural element.

Here, we had test results as shown on table.12 without positive pressure in test room. These data was taken and recorded as future reference values in order to see how

Table.12 *Turbocharger filter with silencer Performance test measurement Results by Argeman.*

PA4-185 Engine HS.400 TurboCharger filter Performance Test Measuments				Date:	13.08.2012
				Place:	TULOMSAS
				Engine No:	XXX
Load (%)	0%	25%	50%	75%	100%
Time	13:30	14:10	14:30	-	-
Rev.	600	1500	1500	1500	1500
Load (hp)	0	630	1200	-	-
Δp room (mmWC)	0	0	0	-	-
Δp T/C Fore (mmWC)	-	10	31	-	-
Δp T/C Aft (mmWC)	-	22	45	-	-
T/C press. Fore (bar)	-	0,26	0,63	-	-
T/C press. Aft (bar)	-	0,27	0,62	-	-

some design changes or modifications result as output values. On above test trials, fore t/c intake filter fitted without filter element inside. Even there is no filtering element inside, two layer of filter casing which shown at figure.7 caused serious pressure drop at aft unit while air was passing through suction channels. At %25 engine loads, 20mmWC permissible pressure drop was exceeded so It required us to cancel two layers of filtering casing. Outer and inner casing faced each other for minimizing air velocity lost while air passing inside. Test trials are being continued. Next phase trials will include positive pressure advantages in engine room.

Results and discussions

Even all inside surface of turbocharger filter casing is covered with absorptive material; there is no serious sound attenuation. It was observed that there is only limited 3-4dB (decibel).On the other hand, Shop trials didn't give us expected some sound attenuation changes even at different loads. Sound attenuation amounts were very close at each performance test steps.

Filter unit inside filled with 40mm thickness in total has great influence at pressure drop. It was observed, even amount of copper filters used as secondary filtration was reduced pressure drop through filtration element decreased small amount in conjunction with thickness. Secondary filtration filter element thickness should be kept as minimum as needed. Otherwise, pressure drop increased over limitations.

There are serious impacts on engine performance either at atmospheric pressure condition or at forced pressurized engine room conditions. In order to get easy breath or supply air to any kind of diesel engine, there should be optimum amount of air pressure at where engine is installed.

Conclusion

According to actual experiment/test and study, the results can be summarized as

follows;

From conceptional design to actual performance tests, research and development programmers provide to produce new products and approaches against customer needs. Providing eligibility criteria on turbocharger filter silencer design processes direct research team to look deeply some specific subjects such as sound absorptive material type selection, thickness, filter element type and thickness, complete design, air dynamics, material selection on manufacturing, atmospheric pressure conditions in engine room. All criteria directly affect while getting optimum required prototype product for turbocharger unit.

The future following trends can be clearly identified such as; higher specific power output to archive less weight per kW, higher engine efficiency, lower exhaust emissions, improved engine reliability and longer times between overhauls, lower manufacturing costs.[Heim,K.]

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