International Journal of Automotive Technology (2024) 25:1077–1090
https://doi.org/10.1007/s12239-024-00089-5

ENGINE AND EMISSIONS, FUELS AND LUBRICANTS

Investigations of Solid Particle Erosion on the Flow Channel Walls of a Radial Turbine for Diesel Engine Applications

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Received: 27 February 2024 / Revised: 21 March 2024 / Accepted: 1 April 2024 / Published online: 17 April 2024

Abstract
Carbon particles, a primary component of diesel engine emissions, cause persistent erosion in the exhaust piping system, inevitably leading to performance degradation. This erosion can result in reduced fuel economy and increased emissions. The effects of three key parameters including solid particle size, turbine *U/C* operating conditions and rotational speed on the erosion characteristics of the flow channels of a radial turbine for vehicle diesel engine applications and their impact on performance were investigated through numerical simulations in the study. The findings indicate that larger particle size and higher rotational speed can significantly lead to the higher erosion rate density of the volute channel and casing wall surfaces. Reducing *U/C* does not substantially affect the distribution of erosion rate density. Centrifugal force will play an important role in the variation of erosion distribution characteristics. Compared to *U/C*, the other two key parameters are sensitive factors affecting turbine performance degradation. Under the same condition for operating 5000 h, 10 μm particles cause a 7.5-fold increase in efficiency loss change rate compared to 0.5 μm particles. The efficiency loss at 140 krpm is 16 times greater than that at 40 krpm.

Keywords Radial turbine · Carbon particles · Diesel engine · Erosion rate · Performance degradation

List of symbols

A	Cross-sectional area of the volute, mm^2
$A0$	Area of the throat of volute flow channel, mm^2
$b(v)$	Impinging velocity function, –
C	Isentropic adiabatic expansion velocity of the flow, m/s
$C(dp)$	Particle diameter parameter, –
CR_φ_i	The contribution rate of the stage efficiency change for each pneumatic component, –
CR_MFP_i	The contribution rate of the stage *MFP* change for each pneumatic component, –
$f(\alpha)$	Incidence angle function, –
k	Sand grain size, μm
l	Number of particles eroding the wall surface per time, –
MFP	Mass flow parameter (characterizing the similarity of flow), kg K^2/(s bar)
m	Mass flow rate, kg/s
mp	Mass flow rate of particles, mg/s
n	Rotational speed, krpm
P	Diesel Engine power, kW
PS	Particle sizes, μm
ps	Pressure side of a blade
Ra	Roughness based on arithmetic mean deviation of contours, μm
r	Radius of the cross-sectional centroid of the volute, mm
ss	Suction side of a blade
T	Erosion time, h
U	Blade tip velocity, m/s
V	Particle impinging velocity, m/s
ε_m	Erosion rate density, kg/(m^2 s)
ρ_{face}	Density of the eroded material, kg/m^3
φ	Adiabatic efficiency of the turbine,

Subscripts

face	Wall surface
local	Local place

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