

The Impacts of Aromatic Contents in Aviation Jet Fuel on the Volume Swell of the Aircraft Fuel Tank Sealants

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ABSTRACT

The impacts of aromatic contents in the aviation jet fuel on the volume swell of fuel tank polythioether and polysulfide sealants were systematically studied in this research. The experimental results revealed the sealant volume swell was dramatically increased as the aromatic content in the fuel was increased. The volume of the PR 1440 polysulfide manganese cured sealant was shrunk when the sealant was soaped in the aviation fuel with aromatic volume content less than 8 vol. % for 28 days at 93°C. The volume of the tested polythioether sealants was never shrunk at the same operating conditions. The experimental results also demonstrated the addition of various additives into the aviation fuel could effectively increase the volume swell of the sealant, increasing the sealant sealing properties. The shrinkage of the PR1440 polysulfide sealant soaped in the low aromatic content fuel at high temperature may be attributed to the material high density, the well-arrangement of the material structure and the high cross linking degree of polymer. This may also explain the fuel leakage phenomena in some aircrafts injected with low aromatic contents fuel in China.

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INTRODUCTION

The high aromatic contents in the jet fuel, especially the naphthalene-based hydrocarbon, could not only lower the fuel combustion performance but also lead to generate more particulate matter (PM) during engine operation. The PM would easily deposit inside the combustion chamber or on the engine blades, causing reduced air flow in the channel and shortage of engine lifetime. More importantly, the PM had been linked to a range of serious respiratory and cardiovascular health problems and long term exposures to PM might result in tens of thousands of excess deaths per year. Thus, there were strict specification limit requirements for aromatic contents in the jet fuel in national standards all over the world. In China the standard for civil aviation jet fuel (GB 6537) required the maximum aromatic contents in the fuel should be no more than 25 vol.%, which was in accordance with American standard ASTM D 1655 and England standard DEF STAN 91-91. Even though there was no minimum limit for aromatic content in the fuel, due to the usage of polysulfide and polythioether as aircraft fuel tank sealants, the aromatic contents in the fuel should not be too low since the fuel must include swellability to ensure the tightness of the aircraft fuel tank. The paraffin in the aviation fuel had low ability to the seal swell and under the environment of high temperature the polysulfide even shrunk.

The responsibility of fuel and chemical airworthiness certification center of civil aviation of administration of China (CAAC) was to continuously monitor the aviation fuel quality to ensure the jet fuel quality and safety. From our long term monitor we found out the aromatic contents in the imported Jet A-1 were typically 10 to 25 vol.% while the aromatic contents in some domestic manufactured No.3 jet fuels were less than 8 vol.%. In some extremely case the aromatic content in the fuel was 1.4 vol. % much lower than the average aromatic contents in the imported jet fuel. However, the newest standard specification for aviation turbine fuel containing synthesized hydrocarbons (ASTM D 7566-2011a) provided both minimum and maximum aromatic contents limit requirements. The standards required the aromatic contents in the fuel should be no less than 8 vol. %. There were occasional aircraft fuel tank leakage reports from aircrew and airline department of aircraft maintenance. We suspected the fuel tank leakage may be associated with the seal shrinkage due to the poor swelling characteristics of the added fuel.

In this research the widely used fuel tank polysulfide sealants PR-1440, PR-1776 and polythioether sealants PR-1826, PR-1828 were selected as model sealants and the impacts of aromatic contents in the aviation jet fuel on the volume swell were systematically studied. The study also

compared the influence of fuel additives on the seal swell ability. The compatibilities of those four sealants with synthesized biofuel were thoroughly studied and recommendation of biofuel application in the civil aviation was also provided in this paper. The experimental results would provide better guidance on aviation fuel quality control and give supportive information to the department of civil aviation administration on publishing aviation circulars.

EXPERIMENTAL

Sealant Preparation: Four different common used polysulfide and polythioether sealants were selected in this research and provided by PPG Industries. The detailed information about the sealants was illustrated in [table 1](#). The procedure to prepare the sealant was as follows: weight appropriate base and curing agent according to the ratios and instructions indicated in the product manual. Then thoroughly mix entire contents on a smooth glass surface with spatula while avoid fast stir to reduce the generation of gas bubble. The well mixed mixture was injected into a dedicated dispensing gun and the uncured sealant was obtained by injection of mixture into the mold. The sealant was cured for 14 days under 25°C with 50% relative humidity. When the ultimate cured hardness of the sealant was above 50 A the sealant was regarded as qualified.

Table 1. Properties of Sealants

Sealant Type	Properties	Specification
PR-1440, B-2	Polysulfide, manganese cured	AMS-S-8802
PR-1776, B-2	Polysulfide, light weighted	AMS-S-3281
PR-1886, B-2	Polythioether	AMS-S-3277 Type I
PR-1828, B-2	Polythioether	AMS-S-3277 Type II

Test Fluid Preparation: The baseline test fluids were prepared according to ASTM D 4054. The formulation of the Jet Reference Fuel (JRF) was as follows: Exxsol D40 37.1 vol. %, Exxsol D80 37.1 vol. %, Aromatic 100 7.5 vol. %, Aromatic 150 15 vol. %, Aromatic 200 2.5 vol. %, tert-Butyl Disulfide 0.73 vol. %, Decanethiol 0.01 vol. %, DiEGME 0.15 vol. %. The test fluids containing different volume percentage aromatic contents were prepared as follows: Based on the formulation of JRF prepare paraffin solution (D40:D80 = 1:1) and aromatic solution (A100:A150:A200 = 3:6:1). Then use the pre-prepared paraffin and aromatic solution to make blend containing 0 vol. %, 4 vol. %, 8 vol. % and 12 vol. % aromatic solution. After that add proper amount of sulfur, mercaptan, fuel system icing inhibitor and lubricity improver into the blend, which was regarded as to be representative of, or a surrogate for, kerosene-type fuels. Besides the test fluids above another three kinds of jet fuels were provided in this research. No.3 Jet Fuel-1 was provided

by Nanning refinery of PetroChina and No-3 Jet Fuel-2 was provided by Luoyang refinery of China Sinopec. Jet A-1 was imported from Korean arrival from port Shanghai. The physical and chemical properties of those three fuels were listed in [table 2](#), [3](#), [4](#). We also tested the effects of aromatic content in aviation biofuel on seal swell ability. Both biofuel components tested here were produced from *Jatropha curcas*, one by PetroChina (Biofuel-1) and one by Sinopec (Biofuel-2). The pure biofuel components were then mixed with No.3 Jet fuel in the volume ratio of 50:50. Analysis indicated the aromatic content in the mixture was equal or higher than 8 vol. %.

Table2. Physical and Chemical Properties of No.3 Jet Fuel-1

Property	Method	No.3 Jet Fuel I
Acidity, total mg KOH/g	D 3242	0.003
Aromatics, vol. %	D 1319	2.1
Sulfur, total mass %	D 1266	0.00012
Distillation temperature, (10 %), °C	D 86	171.0
Distillation temperature, (50 %), °C	D 86	185.0
Distillation temperature, (90 %), °C	D 86	208.0
Final Boiling point, temperature, °C	D 86	229.0
Flash point, °C	D 56	43.5
Density at 15 °C, kg/m ³	D 4052	801.2
Freezing point, °C	D 2386	<-80
Viscosity - 20 °C, mm ² /s	D 445	1.56
Smoke point, mm	D 1322	28
Electrical conductivity, pS/m	D 3624	170

Table3. Physical and Chemical Properties of No.3 Jet Fuel-2

Property	Method	No.3 Jet Fuel II
Acidity, total mg KOH/g	D 3242	0.0058
Aromatics, vol. %	D 1319	14.5
Sulfur, total mass %	D 1266	0.0162
Distillation temperature, (10 %), °C	D 86	172.5
Distillation temperature, (50 %), °C	D 86	190.5
Distillation temperature, (90 %), °C	D 86	218.0
Final Boiling point, temperature, °C	D 86	237.0
Flash point, °C	D 56	45
Density at 15 °C, kg/m ³	D 4052	793
Freezing point, °C	D 2386	-54.5
Viscosity - 20 °C, mm ² /s	D 445	3.664
Smoke point, mm	D 1322	26.2
Electrical conductivity, pS/m	D 3624	261