

Ceradyne's Silicon Nitride for Automotive Applications



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Ceradyne is an ISO 9001 ceramic component manufacturer specializing in the manufacture of silicon nitride components for diesel engine applications. Ceradyne also manufactures advanced technical ceramics for defense and industrial applications. Our material specialization lies in the manufacture of non-oxide ceramics, such as silicon carbide, boron carbide and aluminum nitride, in addition to silicon nitride.



Ceradyne's Silicon Nitride Automotive Products

Ceradyne has been producing high quantities of silicon nitride ceramics (>650,000 pcs/year) for industrial wear applications since 1990. Ceradyne has also participated in a number of ceramic automotive component qualification programs in the U.S. since the early 90's.

These include:

- **Silicon nitride exhaust valves and clevis pins for a heavy-duty diesel application.** The program was successful and culminated in a successful NATO durability qualification test for the engine.



Ceradyne's Silicon Nitride Exhaust Valves

Ceradyne's silicon nitride was selected for this exhaust valve application because of its high temperature strength and mechanical reliability. The valves, combined with other components, allowed the engine to operate at higher temperatures with less heat rejection, resulting in an engine having a higher power density.

Ceradyne's silicon nitride valves are approximately 60% lighter than metal valves, resulting in reduced reciprocating inertia, thereby increasing the fuel efficiency of the engine. The high acoustic damping capacity of silicon nitride reduces engine noise.

- **Silicon nitride tappet inserts for piston applications.** Tests have shown that the use of silicon nitride inserts results in reduced friction relative to standard metal inserts. Wear rates for silicon nitride are a fraction of those of the best powder metal inserts. The compatibility with both cast iron and steel allows flexibility in the selection of cam lobe materials.



Ceradyne's Silicon Nitride Rolling Elements (balls and rollers) for Bearing Applications

- **Silicon nitride roller bearing elements for high performance hybrid roller bearings.** This application takes advantage of the lightweight, high stiffness and high Hertzian contact strength of silicon nitride. These bearings can operate at higher speeds and stress levels with reduced lubrication when compared to metal

roller bearings. Ceradyne's silicon nitride was selected for this application because of its contact fatigue resistance and Ceradyne's capability to machine roller bearing elements with OD crown profiles.

Ceradyne has been successful in introducing its silicon nitride into high volume, automotive production applications. These include:

- **Silicon nitride flat and radius tappet inserts and cam rollers for racing applications.** Our customer is selling these parts commercially for high performance applications in both drag and stock car racing.



Ceradyne's Silicon Nitride Components for Racing Applications

The mechanical reliability and lightweight of Ceradyne's silicon nitride has contributed to the increased durability of these components and the resulting increased engine performance.

- **Silicon nitride cam rollers for heavy duty diesel engines.**

These components have been tested at contact stresses of 350,000 psi (2.4 GPa) for extended time periods.

Silicon nitride cam rollers were introduced into production to solve a wear problem associated with the use of a bronze bearing at the ID of a metal roller. The low coefficient of friction and low wear rates between silicon nitride and the steel shaft eliminated this wear problem. The low weight of the silicon nitride also reduced the rolling inertia lessening the tendency for “scuffing” of the roller and camshaft. The silicon nitride also enabled the fuel injection system to operate at higher pressures allowing the engine to meet emissions requirements.

Ceradyne’s silicon nitride was selected for this program because of its mechanical reliability and its contact fatigue resistance.

- **Silicon nitride rolling elements for a fuel pump for light duty diesel engines.**

These components operate at contact stress levels of 160,000 to 230,000 psi (1.1 to 1.6 GPa) in a diesel fuel environment.



Ceradyne's Silicon Nitride Cam Rollers and Fuel Pump Rollers

Silicon nitride rollers were selected for this application because metal and coated metal rollers failed due to wear and “scuffing”. The silicon nitride components eliminated this problem, while at the same time allowing the pumps to operate at higher pressures.

Ceradyne’s silicon nitride was selected for this application because of its mechanical reliability and contact fatigue resistance.

The successful production applications all emphasize the fact that Ceradyne’s material has the capability of withstanding high Hertzian stresses up to at least 350,000 psi. The rolling contact fatigue behavior of Ceralloy[®] 147-31N silicon nitride is summarized in the following table.

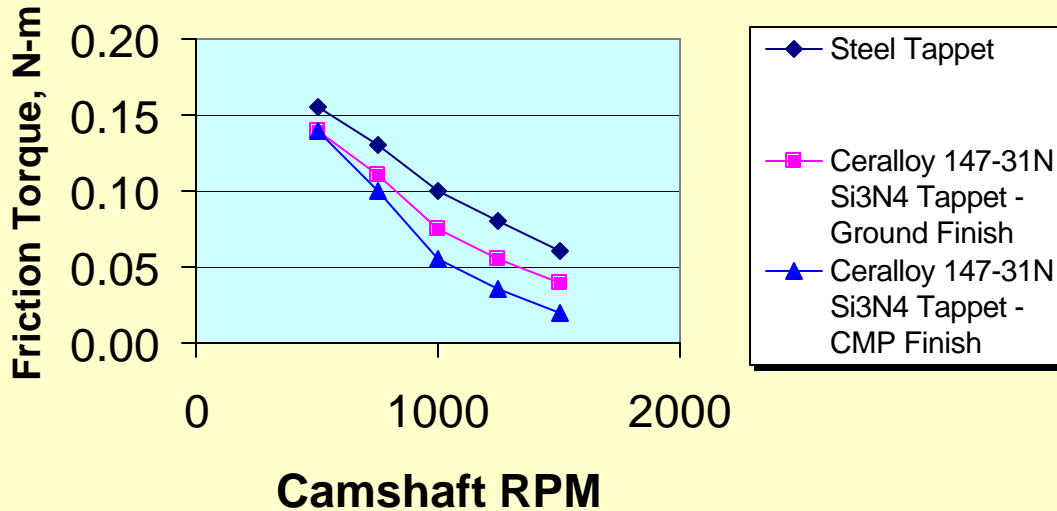
Rolling Contact Fatigue Data for Ceralloy® 147-31N Silicon Nitride

Test type	Stress (GPa)	Cycles (test time)	Result
Rig test of production component	1.1	2.45×10^9 (3000 hrs)	Suspension, no failure
“	1.6	6.36×10^8 (2000 hrs)	“
“	1.5-2.4	6.3×10^7 (1000 hrs)	“
RCF Machine	6.07	Characteristic Life 4.94×10^7 (95.7 hrs)	Weibull Slope 1.2
RCF Machine	6.41	Characteristic Life 4.31×10^7 (83.3 hrs)	Weibull Slope 1.2

This outstanding contact fatigue capability and mechanical reliability is achieved because Ceradyne's silicon nitride is processed by gas pressure sintering and has a microstructure that is fully dense and free of porosity. This, combined with the fact that Ceradyne's silicon nitride has a high fracture toughness, results in a material with high strength and reliability.

Ceradyne's silicon nitride also exhibits reduced friction when in contact with either cast iron or steel, as shown in the following table. Ceradyne's silicon nitride components are operating successfully in both oil lubricated and diesel fuel environments.

Friction Torque Tappet Insert vs Steel Camshaft



Attached is a data sheet describing the properties of our Ceralloy[®] 147-31N silicon nitride material. Further information on our products and company can be found at www.ceradyne.com.

Ceradyne's silicon nitride components have been successful in providing solutions to specific problems involving high volume automotive applications.

The successful applications involve components having high contact stresses combined with tribological wear, corrosion and lubrication problems. Ceradyne's silicon nitride components have solved warranty problems while providing the enabling technology to increase system capabilities and performance.

Typical Properties of Ceralloy® 147-31N Silicon Nitride

General			
Process	SRBSN	Color	Black
% Silicon Nitride	93	Density (g/cc) (% Theoretical)	3.211 >99.5
Mechanical			
Flexural Strength (B50) (MPa) @ RT	800	Elastic Modulus (GPa)	310
@ 1000 °C	800	Poisson's Ratio	0.27
@ 1100 °C	525	Hardness (HV5) Kg/mm ²	1800
@ 1200 °C	425	Fracture Toughness (MPam ^{1/2})	5.5 – 6.5
@ 1300 °C	275		
Weibull Modulus	15 - 30		
Thermal			
Thermal Expansion Coefficient 10 ⁻⁶ /°C; (RT – 1000 °C)	3.1	Thermal Conductivity (W/mK) @ 25 °C	25
Electrical			
Electrical Resistivity (ohm-cm) @ RT	>10 ¹⁴	Loss Tangent @ 1 MHz	0.0005 – 0.0009
Dielectric Constant @ 1 MHz	7.9 - 8.1	Dielectric Strength (kV/mm)	211

Note: Property values are typical and should not be considered specifications.



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