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Modelling and Thermal Analysis of Ultra High Temperature Ceramic Composite Wankel engine Housing

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ABSTRACT: *Mechanical properties of ceramic composites play an important role in the ultra-high temperature applications.ZrB_2-SiC is one of the widely used Ultra high temperature composite material. These materials can also be applied in automobile industries. In this study, ZrB_2 doped with SiC the composite material applied to Wankel engine housing.*
Thermal and static analyses are done on the present model of Wankel engine housing and results are obtained.
KEY WORDS: *Ceramic composites, Pressure, Rotary engine, Thermal resistance, Ultra high temperature materials, Wankel engine.*

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I. Introduction

Wankel engine, commonly referred as rotary engine is a type of internal combustion engine which was invented by German engineer Felix Wankel. This engine converts pressure energy to mechanical energy by rotating motion of rotor. It is commonly used in engines where high power to weight ratio is required. This is primarily used because it produces three power pulses per rotor revolution. In the basic single-rotor Wankel engine,the oval like epitriochoid shaped housing surrounds a three-sided rotor.

Despite of many advantages with Wankel engine there are some other disadvantages which results with less usage when compared to reciprocating engines. Some of them include thermal stresses inducing in the housing, apex seal lifting and slow combustion. Off these, thermal stresses play a major role as it produces vastly different temperatures in each separate chamber section. So, in order to reduce these thermal stresses high thermal resistant composite material is used.

Ultra high temperature composite materials (UHTCm) are generally used in Aerospace, Marine industries. This is due to their high thermalresistance. Ultra high temperature based ceramic composites are noted as advanced materials .Therefore SiC is added to ZrB_2, acts as a strengthening phase to enhance its mechanical performance. The high melting temperatures of both ZrB_2 and SiC adds up to the requirements.

Table 1: The details about the physical properties of ZrB_2 doped with 30% of Sic.

Material	Density (g/cm3)	Relative Density	Hardness (GPa)	E (GPa)	σ_f (MPa)
ZrB_2-30vol.%SiC	5.41	~100%	24±1	485±10	1026±34

Properties of composite material

Table 2: The physical and thermal properties of ZrB_2 doped with 30% SiC.

MATERIAL	ZrB2-SiC
Density	5.4 g/cm^3
Flexural strength	480 MPa
Compressive strength	2600MPa
Tensile strength	50.34 MPa
Fracture toughness	3.4 MPa·m½
Thermal conductivity	96-143W.(m.K)$^{-1}$
Coefficient of thermal expansion	4x10^{-6} k^{-1}
Elastic modulus	490 GPa
Poisons ratio	0.149

Table 3: The properties of Inconel 625,conventional material used for Wankel engine housing.

MATERIAL	INCONEL 625
Density	8.44 g/cm^2
Hardness	145-240
Yield strength	528 MPa
Tensile strength	825 MPa
Impact strength	156.6 J
Thermal conductivity	25 W.(m.K)$^{-1}$
Coefficient of thermal expansion	5.5x10^{-6} k^{-1}
Elastic modulus	147 GPa
Poissons ratio	0.33

II. Experimental Tests And Discussion

2.1 Static structural

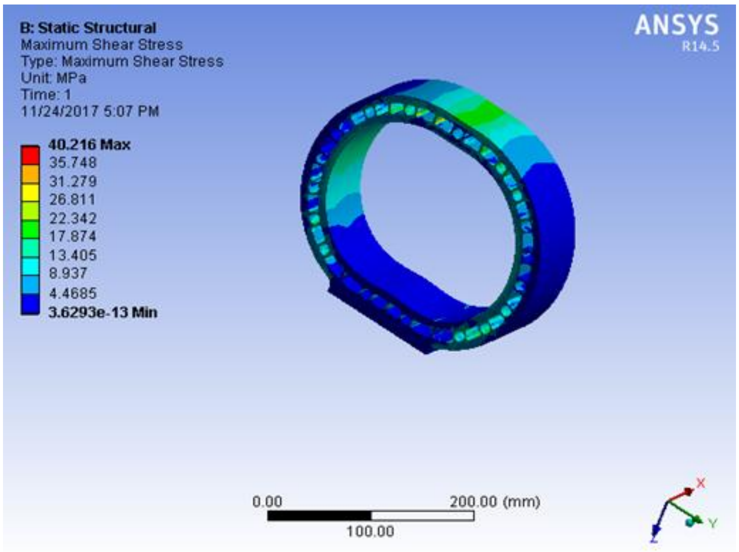

Fig. 1: The shear stresses induced in Wankel engine housing made of ZrB_2-SiC. The applied pressure is 1.6MPa and the resultant maximum shear stresses are above. The addition of ceramic material to ultra-high temperature resistance material improves the strength of the material..Shear stress is inversely proportional to poisons ratio. The poisons ratio of Inconel 625 is higher when compared to ZrB_2-SiC.
Hence the shear strength of Inconel 625 is less when compared to ZrB_2-SiC.

2.2 Thermal results

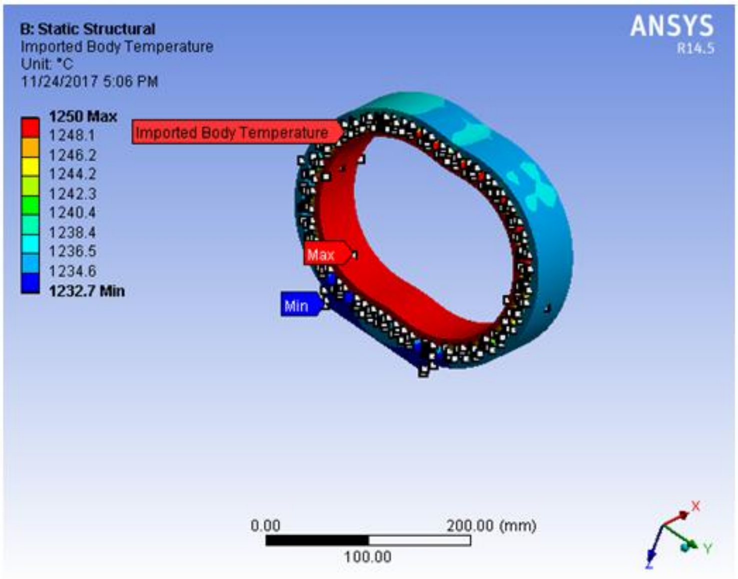

Fig.2: The imported body temperature of the housing when a temperature of 1250°c is applied. The exhaust temperature of Wankel engine is approximately 1100°C. It is clear that the failure rate is low when we use ZrB_2-SiC when compared to Inconel 625. This is due to the addition of ceramics to Ultra high temperature; there results in an improvement in not only thermal properties, but also physical properties as ceramics are mostly used in high temperatures. It is clear that the failure rate is low when we use ZrB_2-SiC when compared to Inconel 625. .This is due to the addition of ceramics to Ultra high temperature; there results in an improvement in not only thermal properties, but also physical properties as ceramics are mostly used in high temperatures. Even though the thermal conductivity of Inconel 625 is higher but the coefficient of thermal expansion is higher for ZrB_2-SiC.The normal operating temperatures of Inconel 625 ranges from 800^0C to 1093^0C,but due to certain applications they are subjected to different heat treatment process. The maximum temperature after annealing is 1204^0C which is less than the temperature induced in the ZrB_2-SiC material. This results in higher thermal stress resistance.

2.3 Temperature at random points

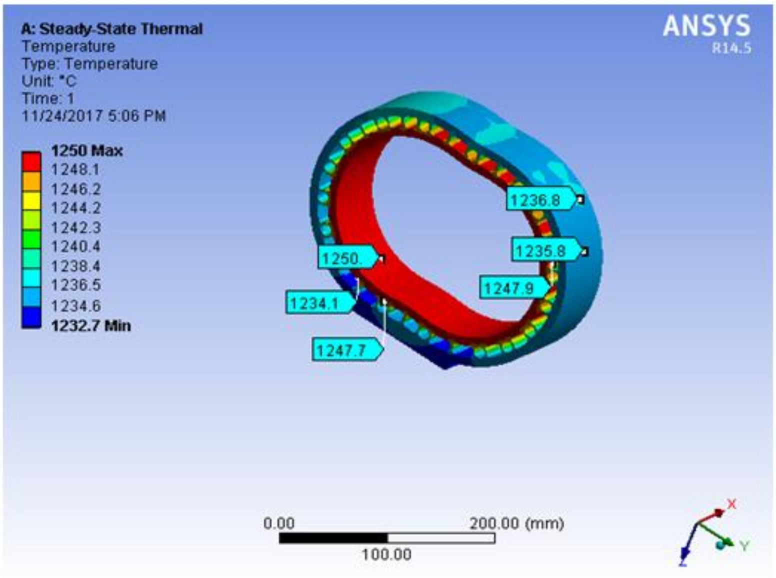

Fig.3: The temperature distribution in the engine housing. The temperature at inner surface is resulted to be 1250°C and the temperature at outer surface is resulted to be 1236.8°C.Inconel has a maximum temperature resistance of 1204^0C where as ZrB_2-SiC has a temperature resistance of about 2300^0C.This results in less thermal stress due to distribution of temperature all over the housing.
The advantage of using this material is its lower density being 5.3g/cm^3.Hence this does not increase the engines weight and results in increasing its efficiency.

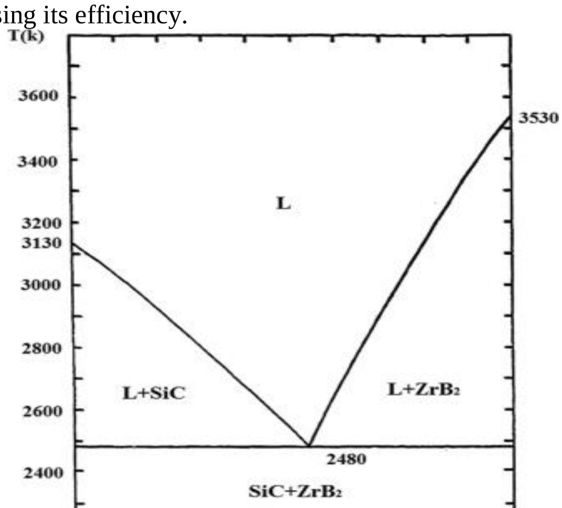

Fig.4: The phase diagram of ZrB_2-SiC. It is clear that on adding 30% of SiC to ZrB_2 results in decreasing its weight and increase in its hardness is due to addition of ceramics like SiC. Carbon elements are known for their

high strength and stability. Addition of carbon to silicon results in silicon carbide which is a commonly used ceramic composite.

As the phase change temperatures of both Zirconium di boride and silicon carbide are high when compared to the exhaust temperature in Wankel engine, there is less possibilities of failure due to thermal stresses.

2.4 Equivalent von-mises stresses:

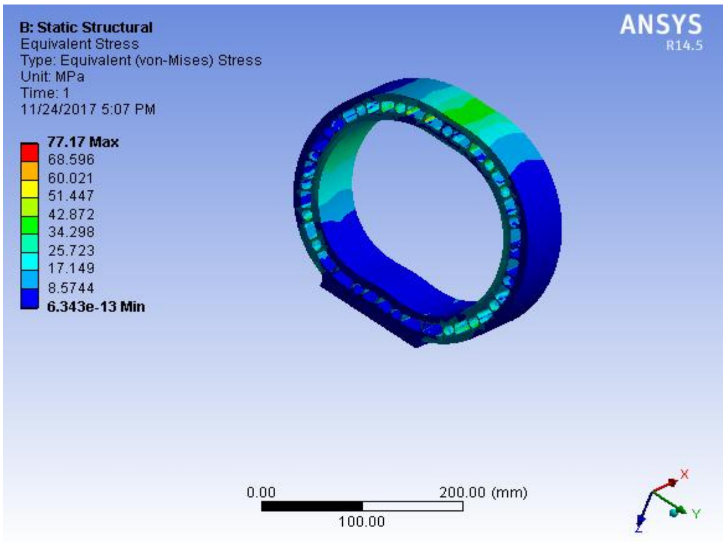

Fig.5: The above figure shows the equivalent shear stresses (equivalent von mises stresses) induced in the Wankel housing. From the above figure it is clear that a normal stress of 38MPa acts on the housing and the maximum stress being 77.2MPa approximately.

III. Conclusion

1. Wankel engine housing made of ultra high temperature resistant ceramic composite material i.e ZrB_2 doped with 30% SiC and can withstand temperature upto 1250^0C when compared with conventional material Inconel-625.

2. The maximum stresses that can be induced in the material used in the housing is 40.15MPa which is compared with conventional material housing.Hence there is lesser scope of failure due to induced stresses.

References

[1]. **[1].**http://www.ijmer.com/papers/[NC-%20DATES2K16]%20-%202016/MECH/Version-2/(Mech)%2039-45.pdf
[2]. **[2].**Yamamoto, Kenichi (1981). Rotary Engine. Toyo Kogyo.
[3]. **[3].**Frank Jardine (Alcoa): "Thermal expansion in automotive engine design", SAE Journal, Sept 1930, pp. 3.
[4]. **[4].**F Feller and M I Mech: "The 2-Stage Rotary Engine—A New Concept in Diesel Power" by Rolls-Royce, The Institution of Mechanical Engineers, Proceedings 1970–71, Vol. 185, pp. 139–158, D55-D66. London.
[5]. **[5].**Yamaguchi, Jack K (2003). The Mazda RX-8: World's First 4-door, 4-seat Sports Car Plus Complete Histories of Mazda Rotary Engine development and Rotary Racing Around the World. Mazda Motor. ISBN 4-947659-02-5.
[6]. **[6].**https://link.springer.com/article/10.1007/s11706-010-0091-3
[7]. **[7].**http://stars.library.ucf.edu/cgi/viewcontent.cgi?article=2406&context=etd
[8]. **[8].**http://www.specialmetals.com/assets/smc/documents/alloys/inconel/inconel-alloy-625.pdf
[9]. **[9].**http://etd.fcla.edu/CF/CFE0005060/Final_Thesis.pdf

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