COMPARE AND ANALYSIS OF PISTON RING IN A COMPOSITION OF Al-SiC WITH GREY C.I USING ANSYS

Sabareesan S[1], Prakash Kanna G[2]
[1]Assistant Professor: Department of Mechanical Engineering
PSNA College of Engineering and Technology, Dindigul.
[2]Assistant Professor :Department of Automobile Engineering
RVS Etucational Trust's Group of Institutions, Dindigul.
[1]Sabaree1987@gmail.com, [2]kanna.gp102@gmail.com

Abstract— **In this work an attempt has been made to increase the reliability of piston using Al-Sic composites as an alternative material for the piston compression rings. The piston ring is one of the main components of an internal combustion engine. Its main purposes are to seal the combustion chamber of the engine. Elastic finite element models are used to calculate the stresses of piston ring. Try to change the piston ring material to reduce the wear, increasing the life time of the piston ring. Aluminium matrix composites are finding increased application in Automotive, Aircraft and Aerospace industries and hold the greatest promise for the future growth. The finite element analysis of the Al-Sic composite piston compression ring was done using Ansys software. The temperature, principal stress and principal strain distribution over the entire surface of the piston compression ring were obtained. The stresses were found to be well below the allowable stress for the Al-Sic composites.**

Keywords*— principal stress, principal strain, ansys, Al-Sic composite, combustion chambers.*

I. INTRODUCTION

The piston ring is one of the main components of an internal combustion engine. Its main purposes are to seal the combustion chamber of the engine, minimize the friction against the cylinder liner but also transfer heat from the piston to the cooled cylinder liner. Another important property of the piston ring is to evenly distribute oil along the cylinder liner in order to avoid engine seizure.

One cylinder in a modern marine two-stroke diesel engine usually contains four to five piston rings referred to as the ring pack and for each of the piston rings there is a corresponding piston ring groove at the piston in which the piston ring is mounted. The top ring of the ring pack normally has a base material of higher grade cast iron and sometimes the

ring is thicker and higher than the other piston rings in the ring pack. These design modifications are added because the top ring is working under higher thermal and mechanical load compared to the lower rings.,

Al-sic composite piston compression rings have been fabricated through casting and powder metallurgy processes. The total deformation, shear stress and von-mises stress of the Al-sic and cast iron guides were analyzed and compared.

The finite element analysis of the piston rings was done using ANSYS software. The temperature, stress and strain distribution over the entire surface of the piston compression rings was obtained.

II. LITRARURE REVIEW

Aluminium Silicon Carbide (AlSiC) metal matrix composite (MMC) materials have a unique set of material properties that are ideally suited for all electronic packaging applications requiring thermal management. The AlSiC coefficient of thermal expansion (CTE) value is compatible with direct IC device attachment for the maximum thermal dissipation through the 170 – 200 W/mK thermal conductivity value material. Additionally, the low material density of AlSiC makes it ideal for weight sensitive applications such as portable devices.[1]

The Al-SiCp composite piston compression rings also have higher Rockwell hardness, radial crushing strength and wear resistance than the cast iron piston compression ring presently used in pistons [2]. The radial crushing strength, hardness, and wear resistance of the Al-SiCp composite and cast iron piston compression rings were measured and compared [2,3].

Al–SiC composites containing four different weight percentages 5%, 10%, 20% and 25% of SiC have been fabricated by liquid metallurgy method. Friction and wear characteristics of Al–SiC composites have been investigated under dry sliding conditions and compared with those observed in pure aluminium. Dry sliding wear tests have been carried out using pin- on-disk wear test rate normal loads of 5, 7, 9 and 11 Kgf and at constant sliding velocity of 1.0m/s. Weight loss of samples was measured and the variation of cumulative wear loss with sliding distance has been found to be linear for both pure aluminium and the composites. It was also observed that the wear rate varies linearly with normal load but lower in composites as compared to that in base material. [4, 5]

The wear mechanism appears to be oxidative for both pure aluminium and composites under the given conditions of load and sliding velocity as indicated by scanning electron microscope (SEM) of the worn surfaces. Further, it was found from the experimentation that the wear rate decreases linearly with increasing weight fraction of silicon carbide and average coefficient of friction decreases linearly with increasing normal load and weight fraction of SiC. The best results have been obtained at 20% weight fraction of 320 grit size SiC particles for minimum wear [6, 7, 8]

III. CONSTRUCTIVE VIEW OF PISTON RING

The Piston rings purpose is to disperse the heat from the piston rings. High in strength for durability, the heat conductivity and wear resistance rates are all an absolute requirement on the Piston rings material choice. The selected materials as used by the car manufacturers are mainly chosen for the cost savings reasons and are not designed to cope with high piston speeds and excessive loads.

`

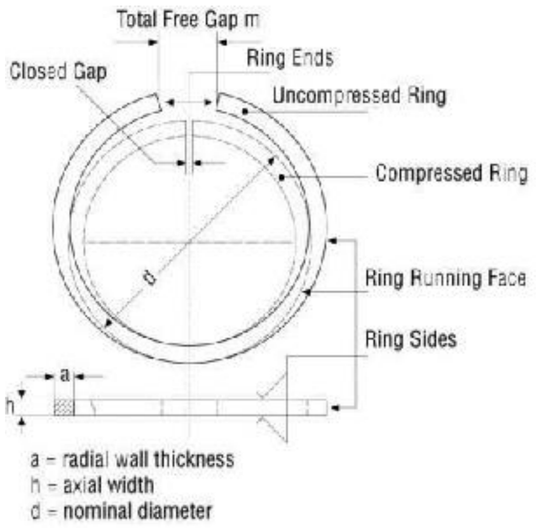


Fig: Piston ring

The TOMEI Piston rings are made from Phosphorus Bronze material for its characteristics of efficient heat dissipation, from the Piston rings to the Cylinder Head. Also for its high durability characteristics in extreme conditions which is strong against cracking.

IV. MATERIAL PROPERTIES

A. *Gray Cast Iron(CI) properties*

Mechanical property reference data for various grey cast irons, includes Tensile strength, Compressive Strength, Shear Modulus of Rupture, Tensile Modulus of Elasticity, Torsional Modulus of Elasticity, Endurance Limit and Brinell hardness data.

The American Society for Testing Materials (ASTM) numbering system for grey cast iron is established such that the numbers corespond to the minimum tensile strength in KPSI. Thus an ASTM No. 20 cast iron has a minimum tensile strength of 20 KPSI. Note particularly that the tabulations are typical values. Multiply strength in KPSI by 6.89 to get strength in MPa.

Steels given for comparison purposes. Tensile and hardness given as rolled and heat treated by water quench and tempered at 425°F. The SAE 1050 heat treated is roughly the properties of most anvils. However the temper condition given is softer. Use the SAE 1095 temper for anvils.

IRON	Shear			Modulus of Elasticity			
ASTM Number	Tensile strength KPSI	Compressive strength KPSI	modulus of rupture KPSI	MPSI Tension	MPSI Torsion	Endurance limit KPSI	Brinell Hardness Hb
20	22	83	26	9.6 - 14	3.9 - 5.6	10	156
25	26	97	32	11.5 - 14.8	4.6 - 6.0	11.5	174
30	31	109	40	13.0 - 16.4	5.6 - 6.6	14	201
35	36.5	124	48.5	14.5 - 17.2	5.8 - 6.9	16	212
40	42.5	140	57	16.0 - 20	6.4 - 7.8	18.5	235
50	52.5	164	73	18.8 - 22.8	7.2 - 8.0	21.5	262
60	62.5	187.5	88.5	20.4 -	7.8 -	24.5	302

Cast iron is a brittle virtually non-maleable metal that is considered generally inflexible. Cast iron is NOT the metal worked by blacksmiths. It cannot be forged. Cast iron is worked by melting to a liquid and pouring in molds, then by sawing, filing, machining (chip making methods). The stiffness and dampening properties of cast iron make it an excellent material for machine tool frames and parts

B. *Aluminium Metal Matrix composites (Al-MMCs) properties*

Aluminium, as the matrix material, provides the basis of the most of the commercial and academic researches on MMCs. Aluminium has well suited properties for use a matrix material, which are:

- Light weight,
- Environment resistance,
- Useful mechanical properties.

In addition to the properties stated above, one of the most important properties of aluminium for its use as the most popular matrix material is its melting point. Its melting point is high enough to satisfy many application requirements and, yet low enough to provide the reasonably convenient composite processing. Aluminium matrix composites have a large range of applications especially in the automotive industry due to its applicability for the mass production.

C. *Silicon Carbide Piston ring Properties*

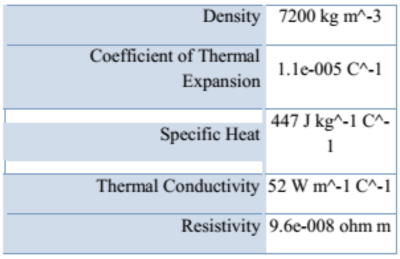
Silicon Carbide Properties			
Mechanical	**SI/Metric (Imperial)**	**SI/Metric**	**(Imperial)**
Density	gm/cc (lb/ft^3)	3.1	(193.5)
Porosity	% (%)	0	(0)
Color	—	black	—
Flexural Strength	MPa (lb/in^{2}x10^3)	550	(80)
Elastic Modulus	GPa (lb/in^{2}x10^6)	410	(59.5)
Shear Modulus	GPa (lb/in^{2}x10^6)	—	—
Bulk Modulus	GPa (lb/in^{2}x10^6)	—	—
Poisson's Ratio	—	0.14	(0.14)
Compressive Strength	MPa (lb/in^{2}x10^3)	3900	(566)
Hardness	Kg/mm^2	2800	—
Fracture Toughness K_{IC}	MPa•m$^{1/2}$	4.6	—
Maximum Use Temperature (no load)	°C (°F)	1650	(3000)
Thermal			
Thermal Conductivity	W/m•°K (BTU•in/ft^2•hr•°F)	120	(830)
Coefficient of Thermal	10^{-6}/°C (10^{-6}/°F)	4.0	(2.2)
Specific Heat	J/Kg•°K (Btu/lb•°F)	750	(0.18)
Electrical			
Dielectric Strength	ac-kv/mm (volts/mil)	—	semiconductor
Dielectric Constant	—	—	—
Dissipation Factor	—	—	—
Loss Tangent	—	—	—
Volume Resistivity	ohm•cm	10^2–10^6	dopant dependent

V. STRUCTURAL ANALYSIS BY ANSYS SOFTWARE

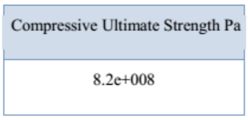
Structural analysis is probably the most common application of FEM. The term structural implies not only piston ring structures such as bridges and buildings, but also naval aeronautical and mechanical structures such as ship, nulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts and tools. Seven types of structural analysis available in the ANSYS Families of products are shown below.

i. Static Analysis
ii. Modal Analysis
iii. Harmonic Analysis
iv. Transient Dynamic analysis
v. Spectrum Analysis
vi. Buckling Analysis
vii. Explicit Dynamics Analysis

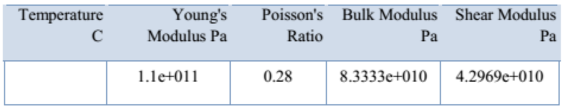
A. *Gray Cast Iron(CI) piston ring input properties*



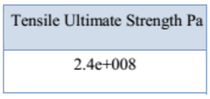
Density	7200 kg m^-3
Coefficient of Thermal Expansion	1.1e-005 C^-1
Specific Heat	447 J kg^-1 C^-1
Thermal Conductivity	52 W m^-1 C^-1
Resistivity	9.6e-008 ohm m



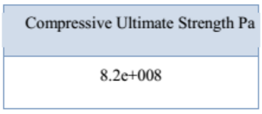
Compressive Ultimate Strength Pa
8.2e+008



Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	1.1e+011	0.28	8.3333e+010	4.2969e+010

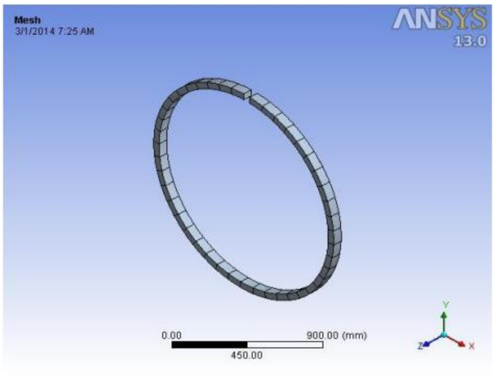


Tensile Ultimate Strength Pa
2.4e+008

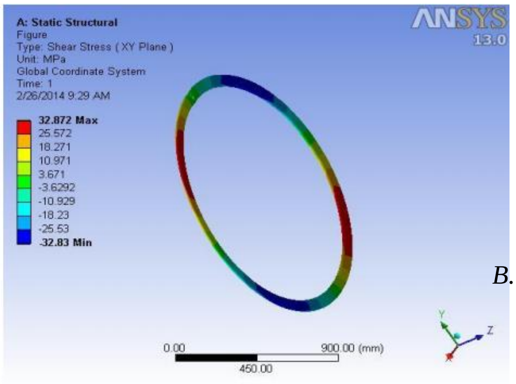


Compressive Ultimate Strength Pa
8.2e+008

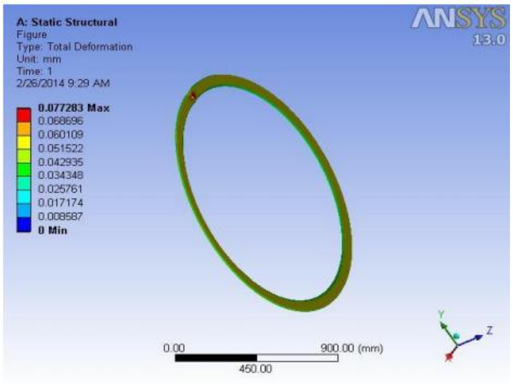
- *MESHING for CI*



- *MAXIMUM SHEAR STRESS for CI*



- *TOTAL DEFORMATION for CI*



- *VON-MISES STRESS for CI*

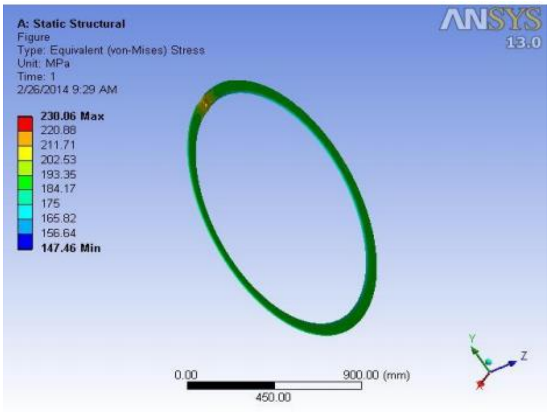


Table for gray cast iron analyzing values

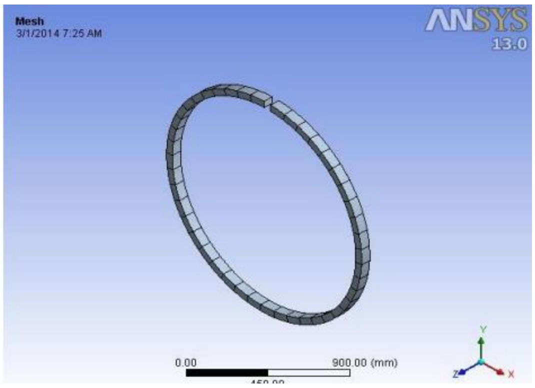
S.No	Object Name	Minimum	Maximum
1	Meshing	0	1
2	Maximum Shear Stress	-32.83MPa	32.872MPa
3	Total Deformation	0mm	0.077283mm
4	Von-Mises Stress	147.46MPa	230.06MPa

B. Aluminium Silicon carbide piston ring input properties

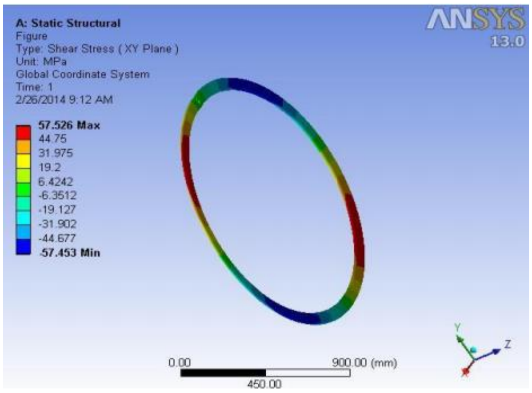
Density	2788 kg m^-3
Thermal Conductivity	168 W m^-1 C^-1

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	8.6e+010	0.32	7.963e+010	3.2576e+010

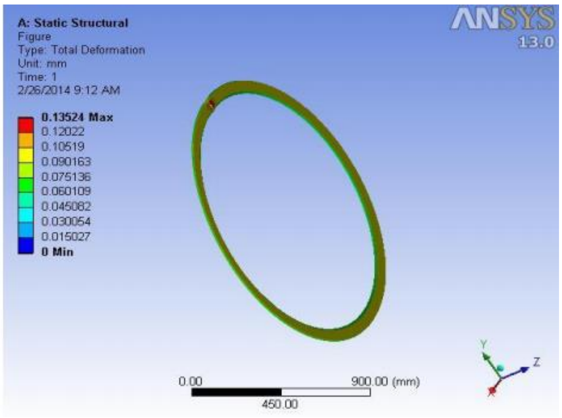
- *MESHING for Al-SiC*



- *MAXIMUM SHEAR STRESS for Al-SiC*



- *TOTAL DEFORMATION for Al-SiC*



- *VON-MISES STRESS for Al-SiC*

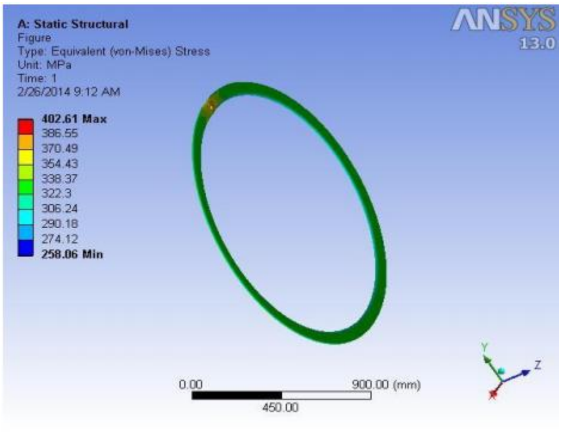


Table for Al-Sic composite material analyzing values

S.No	Object Name	Minimum	Maximum
1	Meshing	0	1
2	Maximum Shear Stress	-57.453MPa	57.526MPa
3	Total Deformation	0 mm	0.13524 mm
4	Von-Mises Stress	258.06MPa	402.61MPa

VI. THERMAL ANALYSIS BY ANSYS SOFTWARE

ANSYS is capable of both steady state and transient analysis of any solid with thermal boundary conditions. Steady-state thermal analyses calculate the effects of steady thermal loads on a system or component. Users often perform a steady-state analysis before doing a transient thermal analysis, to help establish initial conditions. A steady-state analysis also can be the last step of a transient thermal analysis; performed after all transient effects have diminished. ANSYS can be used to determine temperatures, thermal gradients, heat flow rates, and heat fluxes in an object that are caused by thermal loads that do not vary over time. Such loads include the following:

i. Convection

ii. Radiation

iii. Heat flow rates

iv. Heat fluxes (heat flow per unit area)

v. Heat generation rate (heat flow per unit volume)

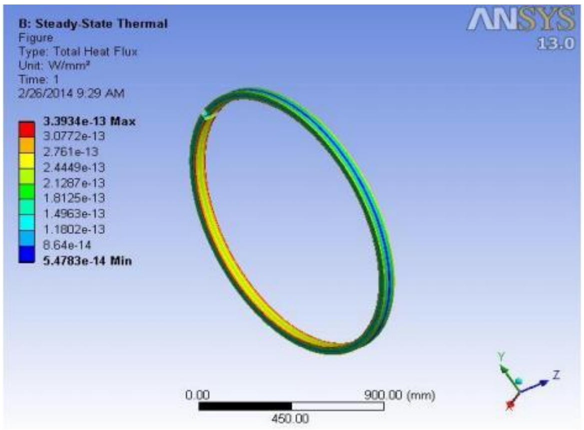
vi. Constant temperature boundaries vii. Explicit Dynamics Analysis

A steady-state thermal analysis may be either linear, with constant material properties; or nonlinear, with material properties that depend on temperature. The thermal properties of most material vary with temperature. This temperature dependency being appreciable, the analysis becomes nonlinear. Radiation boundary conditions also make the analysis nonlinear. Transient calculations are time dependent and ANSYS can both solve distributions as well as create video for time incremental displays of models

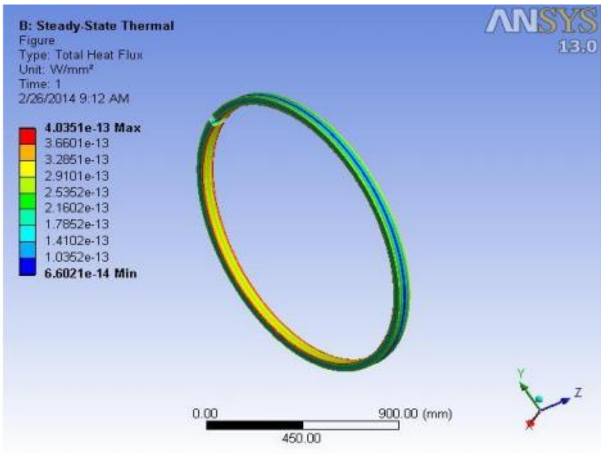
- *Input thermal details*

Object Name	Total Heat Flux	Temperature
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Total Heat Flux	Temperature
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Integration Point Results		
Display Option	Averaged	
Results		
Minimum	9.247e-007 W/m^2	460. °C
Maximum	3.2414e+007 W/m^2	620.17 °C
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

- *Thermal Analysis Of Gray Cast Iron Piston Rings Total Heat Flex*



- *Thermal Analysis Of Al-Sic Composite Material Piston Rings Total Heat Flux*



VII. COMPARISON OF RESULTS

Particulars	Cast Iron		Al-Sic	
	Minimum	Maximum	Minimum	Maximum
Meshing	0	1	0	1
Maximum Shear Stress	-32.83MPa	-32.872MPa	-57.453MPa	57.526MPa
Total Deformation	0mm	0.077283mm	0 mm	0.13524 mm
Von-Mises Stress	147.46MPa	230.06MPa	258.06MPa	402MPa

VIII. CONCULSION

The existing material is LP 8 lamellar cast iron , which has more weight and also has on total deformation, von-misses stress are very high , but in our work we choose Al-SiC as an alternative material for the LP 8 lamellar Cast Iron. which is less than the Cast Iron, also has less weight as that of cast iron. so it can withstand for longer life.

This suggests that the Al-SiC composites have the enough potential as an alternative material for the piston compression rings.

References

[1] R.W. Adams, B.E. Novich, D.Kane, K. Brantferger, R.Oberle and S.Chai, ―A Lightweight High Thermal Composite Microwave Module Package Proceedings of Government Microcircuit Applications Conference (GOMAC), Digest of Papers , Vol. 20, pp 454-456 November 1994.

[2]. Kabat, D. M., Garwin, Ipiston. Jrings. and H analysis, Reliability and test – result 2.446.

[3]. Meyer, Terrence R. and White, Robe deformation and asymmetry on exhaust piston rings thermo-mechanical stresses‖,981034,SAE1998, ppPape.1515-1523.

[4]. Naher, S., Brabazon, D. and Looney casting Journal process of Materials Processing Technology, Vol. 143-144, pp. 567-571.

[5]. Balasivanandha, S., Kaarunamoorthy, L., Kaithiresan, S. and Mohan, B. (2006), of―Influence stirring speed and stirring time on distribution of particles in cast Journal metal of Material matrix Processing compos Technology, Vol. 171, pp. 268-273.

[6]. Vinod Junju , M.V. Mallikarjun and Venkata Ramesh Mamill (July 2012), Issue 2, Vol.5 International Journal of Emerging trends in Engineering and Development Thermo mechanical analysis of diesel engine piston using ceramic crown

[7]. Ajay Raj Singh Dr. Pushpendra Kumar Sharma ISSN : 2248-9622, Vol. 4, Issue 1 (Version 3, January 2014, pp.94-102),

[8]. Ondřej CHOCHOLATÝ, Jiří HÁJEK, Antonín KŘÍŽ, Jan VlČEk comparison of wear resistance of chromium coatings for piston rings using pin-on-disc test and engine test 23. - 25. 5. 2012, Brno, Czech Republic, EU

[9]. Hou Shunqiang, a, Zhang Lili,b and Zhang Xiaoyan Friction Analysis for Piston Ring of Seal Device in the Stirling Engine 2nd International Conference on Electronic & Mechanical Engineering and Information Technology (EMEIT-2012)

[10].Dr.Ahmed A. Al-Beiruti, Dr.Basim M. Al-Quraishi& Isam Ezzulddinyousif Thermal Effects on Diesel Engine Piston and Piston Compression Rings.