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"Reduction of Friction in Pneumatic Actuator"

[*]Vivekkumar Kiritbhai Sharma[1], Kishankumar D Prajapati[2]
[1, 2] *Mechanical Engineer*
Corresponding Author: Vivekkumar Kiritbhai Sharma

***Abstract**: There are various problems encountered in the pneumatics actuator in design as well as in manufacturing processes like casting etc. Here, mainly focusing on reduction of the friction that produce in between pneumatic piston-cylinder arrangement during statics and dynamics condition of working of actuators .So, that it can increase the overall working efficiency of pneumatic machine. The idea of project is to maintain the friction in machine as per the application in the heavy loaded and long vehicles like railway trains. For that, use of different coating materials on Piston leads to fulfill this requirement. Coating on Piston ring can be useful to reduce the friction in Piston- cylinder arrangement.*

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I. Introduction

Air brake: The brake system in which compressed air is used in the brake cylinder for the application of brakes is called air brake.

Necessity to introduce the Air Brake in Trains: The existing vacuum brake has got it's own limitations like brake, fading, increased application and release timings etc., In practice it is not reliable for trains running in higher altitudes due to insufficient vacuum levels in brake van and train engine. So to overcome all these, it has became necessary to introduce Air brake system to control the speed of the train and to stop it within a reasonable distance, irrespective of length, load of the train distance covered and altitude of the train.

II. Materials Used

The design of a piston in a pneumatic cylinder will vary depending on whether the cylinder will be used for light, medium or heavy duty.

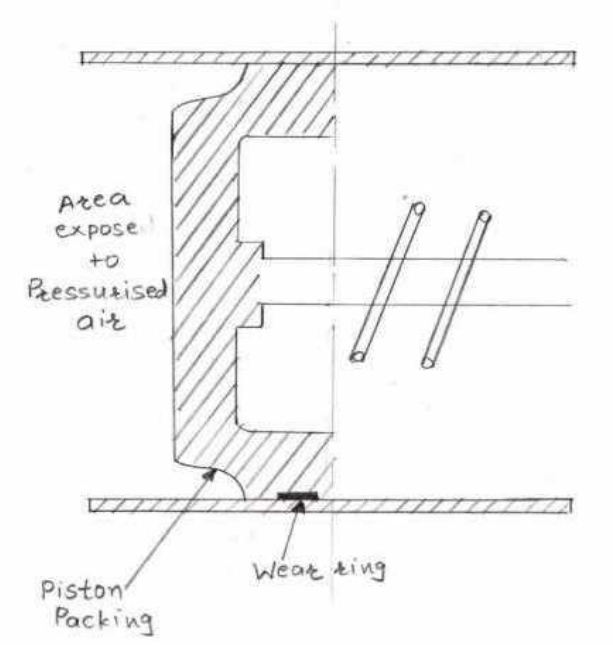
1. Aluminium
2. Brass
3. Cast Iron
4. Steel
5. Nickel-plated brass
6. Nickel-plated Aluminium
7. Stainless steel

Are the most common materials used for the piston. Wherever one part is going to be sliding over another part, materials of different hardness work best. Depending on the level of loads, humidity, temperature, and stroke lengths specified, the appropriate material may be selected. There are traces of many other metals in cast pistons, including copper, nickel, manganese and magnesium, all of these adding somewhat to the overall behavior and strength of the piston.

Friction

Friction is the major loss encounter during the working of pneumatic actuators. Various modification in modern pneumatic actuators reduce the friction at negligible level. The friction in pneumatic actuators are visible in two region that is in static condition and dynamic condition as the pressurized air try to move the piston of pneumatic machine gradually. The behavior of friction in static and dynamic condition are very different in nature. Friction creates heat, promotes wear, and wastes power, so the reduction of friction, by any means, is vital. It is estimated, that from 1/3 to 1/2 of the total energy produced in the world is consumed by friction. It is also estimated that the cost of wear in the U .S. is equivalent to 2/3 the cost of energy. If we add these two together, we see that the cost of friction and wear in the U .S. is equivalent to the cost of energy.

Cylinder body is made up of cast iron or sheet metal. The piston area which come in contact with cylinder body during working condition is made up of either aluminum, steel or any of the previously discuss piston material. As the piston material changes the value of the coefficient of friction changes, so directly there will be change in friction value.

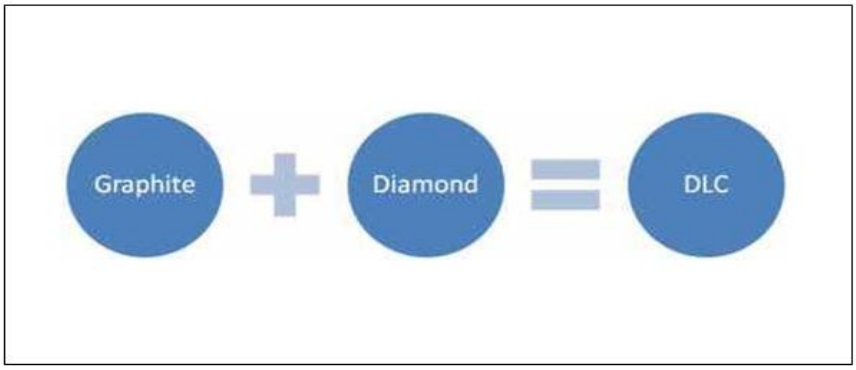


Piston ring is used as friction reducing element. So to increase its durability and life we need a thin film of coating material that could be suitable for above purpose. Various coating materials are available from hardest to softest coating as per the need of work.

Purpose of coating
(1) To increase life of piston ring
(2) To decrease wear rate under high pressure and temperature condition
(3) Able to sustained the effect of jerking during start of brake
(4) To prevent damage to piston ring material

Coating materials
(1) Chromium Nitride
(2) Titanium Nitride
(3) Diamond like carbon (DLC)
(4) silicon dopped-DLC (5) Carbides
(6) synthetic polymers
(7) Magnesium

From above coating materials I have chosen DLC as a coating element, which can be one of the advantageous for coating on a piston ring because we need material which can be flexible to change from hardest one to softest by changing chemical composition.

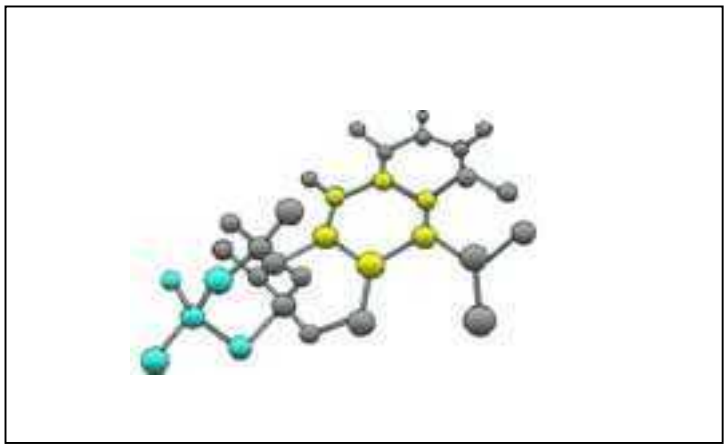


So, DLC is basically composition of two allotropes of carbon that is graphite and diamond. Here diamond is hardest one and on other side graphite is softest.

Diamond like Carbon

DLC is a hybrid element obtain from combination of graphite and diamond by arranging different composition of both. DLC film boast various properties like higher hardness, low friction coefficient, excellent wear resistance. So, these can be one of the best element that could be coated on the piston ring to increase its durability and reliability for many years. DLC film can be defined as amorphous film of irregular mixture of diamond and graphite.

Here young's modulus hardness and electrical properties are similar to that of diamond and thermal properties are similar to that of graphite. So, it uses both the advantages of its compositions.



Structure of DLC

Coating processes of DLC

As DLC is combined element so it has specific methods for coating other than that of general methods normally used. It has been known that properties of DLC is greatly affected by coating conditions and coating methods. DLC films are usually form in vacuum chambers and uses hydrocarbon gases like methane, benzene etc.

Coating Methods

(1) PVD methods (Physical vapour deposition) Uses solid carbon for coating
(2) CVD methods (Chemical vapour deposition) Uses hydrocarbons for coating

Use of DLC

Here, DLC coating is used to reduce friction by controlling graphite because we need material that should have low coefficient of friction so if we are able to give more amount of graphite in DLC then it would be applicable. We also need hardness at some level to make it durable for 10-12 years.

Approximate composition

Diamond = 60% Graphite = 40%

Here content of diamond is taken more that of graphite because by increasing graphite more than that of diamond it would be of softer nature which cannot be applicable particularly to control friction with long lasting usage.

Si-DLC

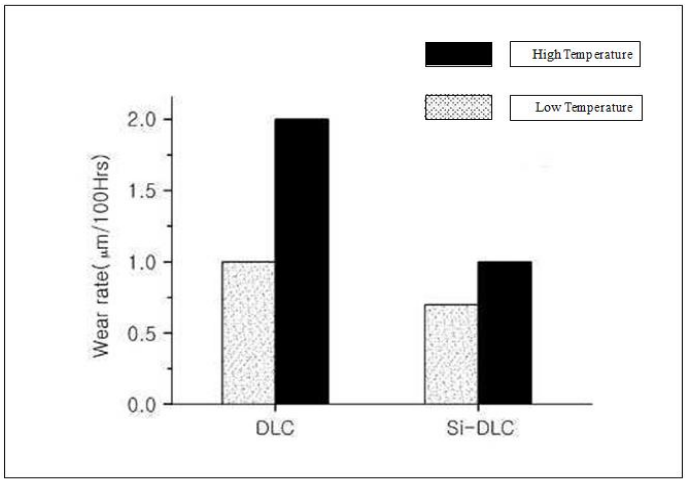
Doping with other elements such as Ti, W, Cr and Si, in order to improve the adhesion and the mechanical properties.

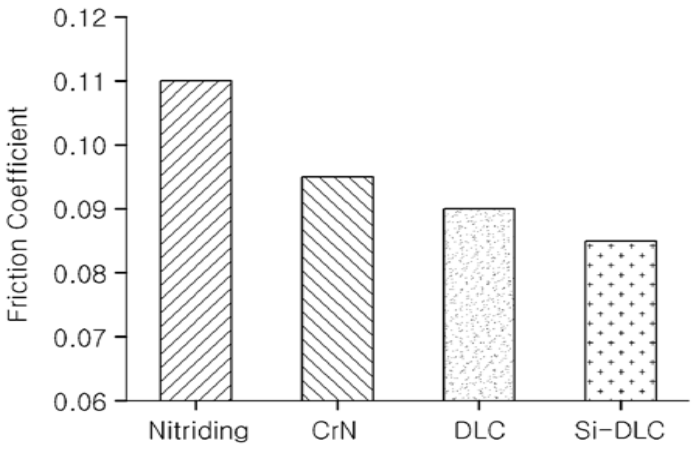
Properties of Si-DLC

(1) Bulk modulus and hardness of the Si-DLC films both decrease with the increasing of the silicon content
(2)Hardness of the Si-DLC films is dependent on diamond and graphite content.

Wear effect observed in DLC and Si-DLC

The figure shows the effect of wear in DLC and Si-DLC on the basis of the temperature consult from the fig. It is clear the effect of the friction is at higher temperature is bitterly control by the Si-DLC than that of the DLC. This is the conclusion that can be making from the discussion done above. New technologies for better control of wear will become possible by combining these effects better.





Durability Test

Durability of the DLC is important as discussed above for the reason of long lasting usage. To test the durability of the DLC, we use specific matter available for the testing the durability of the DLC coated tool or any material on which the DLC is coated. Wiper test is the name of the test. We can check the high durability of mechanical material by the use of this test. The effect of this durability test is clearly defined/observed in the testing of the DLC and Si-DLC. Newly developed hybrid DLC coating now-a-days does not need any check of the durability but for safe side purpose the test is always conducted.

Design of Piston Ring

Main function of the piston ring is to maintain a seal between the cylinder wall and piston .In IC-engine piston ring reduces the friction and better stroke control so, we want to reduce the effect of friction by use of piston ring in the pneumatic actuators.

Types of the piston rings

1. Compression rings
2. Oil scraper ring

Compression rings are provided first and then oil scraper rings are provided. Here in pneumatic cylinder we have decided to provide coating by DLC so, no requirement of lubrication because graphite is auto lubrication property which is present in the DLC. This arrangement of ring can be used as proper lubrication and reduce friction losses. So, scraper ring allow sufficient quantity of lubrication oil to move up during different stroke. This prevents leakage of air from one side to another.

Procedure of piston ring design

1. Material of piston ring

Generally grey cast iron is used for the manufacturing of the piston ring. The selection of the grey cast iron due to excellent property it possesses such as spring characteristics at high temperature, wear resistances. Here it is required to plating above the piston ring.

2. Dimension

The piston ring selected is of rectangular cross-section because the stress distribution is shown. From basis of the strength of material the distribution of the stress in rectangular section can be find out. The stress in the cross-section is at the end and stress at middle of the section is zero.

2 (a) Cross-section dimensions:

The cross section of ring contain Radial width (b) and Axial thickness (h). The procedure to find the dimension is discuss below

Radial width (b)

$b = D\sqrt{(3 * p)/\sigma_t}$

$= 203\sqrt{(3 * 0.6205)/100}$ b = 27.69 mm.

where;

b= radial width

D=bore diameter

σ_t=permissible stress of piston ring material

= 85Mpa to 110Mpa

Axial thickness of piston ring h = 0.7 b to b

so,

h = 0.8*b

h = 0.8*27.69

= 22.152 mm

Here,

h_{min}= 0.7 b

= 0.7*27.69

= 19.383 mm

3. Number of rings

How many number of the ring to be provided is one of the questions in designing the piston ring. It is preferable to provide more number of thin ring than less number of thick rings.

The reason for selection of thin rings:

1. It reduce friction losses and wear
2. better control of sealing effect
3. thin rings occupy less space for fitting and also less area
4. better control over heat transfer

The empirical relation to find number of piston ring is,

$h_{min} = \frac{Z}{10*Z}$

where;

Z= number of ring

19.383= [illegible]

[illegible]

Z = 1.047

= 2 Rings

4. Gap between free ends

A part of ring is slightly cut diagonally as shown in fig. This is provided due to compressed diagonally at the time of assembly. So, gap is indirectly given to get better control of assembly.

G = 3.5 b to 4 b

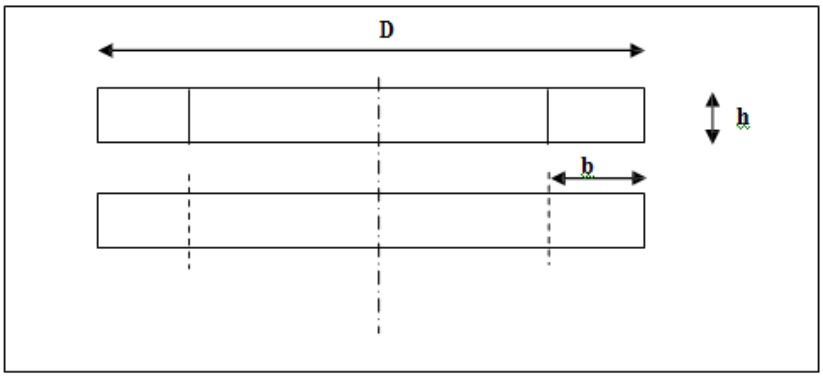
= 3.5* 27.69 to 4 * 27.69

G = 96.916 to 110.76

Take it as

G = 100mm

Where; G = gap between free end.



Ring

5. Width of top land and ring land

Fig shows the groove of the pneumatic piston

Distance from top land is calculated as under

h_1= (t_h) to (1.2t_h)

here,

t_h= piston head thickness

the empirical relation for piston head thickness t_h= 0.032D + 1.5

= 0.032 * 203 + 1.5

= 7.996

= 8.00 mm

So; Distance from top land h_1= (t_h) to (1.2t_h)

= 8 to 1.2*8

= 8 to 9.6

h_1 = 8.5mm

6. Distance between two consecutive ring

h_2 = 0.75h to h

= 0.75* 22.152 to 22.152

= 16.614 to 22.152 h_2 = 20.00 mm

III. Conclusion

Piston ring fits in groove on the outer diameter of a piston to maintain air tightness and reduce friction. In conventional piston ring reduce the friction but it has difficulty maintaining durability so, it needs coating. DLC as a coating element can be one of the advantageous for coating on a piston ring because we need material which can be flexible to change from hardest one to softest by changing chemical composition. Use of silicon as doping for improve its properties, such as its friction coefficient and high temperature anti-oxidation properties and also improved thermal stability, hardness etc. So, Use of Si-DLC is one of the best options as coating foe better result. If from this alternative practical application is possible and reduction in the friction is obtain then the other energy like pressure spend to move piston get reduce and jerking that can be possibly reduce

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