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TITLE:

A DESIGN OF THE HYDRO WANKEL CELL

Topic:

- ● FUTURE AUTOMOTIVE TECHNOLOGY
- ○ INTELLIGENT TRANSPORTATION SYSTEMS
- ○ USER FRIENDLY AUTOMOBILE
- ○ ADVANCED PRODUCTION AND LOGISTICS
- ○ VEHICLES & THE ENVIRONMENT

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Name of the National Society:

Abstract:

Today the world stands at a place where fuel exhausts are choking.The world energy crisis, coupled with the pressing need to reduce air pollution, has placed important emphasis on developing new fuel sources for transportation systems.

Hydrogen, with its almost unlimited supply potential and with its extraordinarily clean combustion properties, emerges as an operationally practical, economically feasible energy source.

The fusion of a wankel engine and a fuel cell gives a wonderful new dimension. The net output given by the engine is both mechanical and electrical.

Place / Date: Hyderabad, India , 29/01/2004

INTRODUCTION:

The world has reached a state of no return,

Today we stand at a place where the exhausts from our automobiles are increasing alarmingly

The world energy crisis, coupled with the pressing need to reduce air pollution, has placed important emphasis on developing new fuel sources for transportation systems. Hydrogen, with its almost unlimited supply potential and with its extraordinarily clean combustion properties, emerges as an operationally practical, economically feasible energy source. The Wankel engine was an ingenious invention by Felix Wankel in 1954; it was an engine of its kind, as it used rotary motion to produce power unlike a conventional IC engines. Fuel cells have come into prominence from the 1980s with the need for a more efficient and eco friendly energy source. Hydrogen has been widely used in wankel engines and fuel cells as a fuel. The processes by which energy is produced in the Wankel engine and the fuel cell are different, the Wankel engine uses a thermo dynamical process like combustion and the fuel cell uses electrochemical reactions, which do not involve any major transfer of heat, thus there arises a question, how two totally different concepts are fused?

OBJECTIVES:

The requirements which are to be met:

- Low pollution
- Optimum efficiency
- Compact nature of the engine
- Low operating temperature using hydrogen engines
- High power density
- Low vibrations and noise

- Good pick up in the engine
- Increase safety measures
- Better operation in colder climates

PROCESS DESCRIPTION:

The Hydro wankel cell works on the basic ideas of Wankel engine and fuel cells into account.

The Wankel engine design is governed by the following equations

Using coordinate geometry

$X = e\cos 3\alpha + R\cos\alpha$

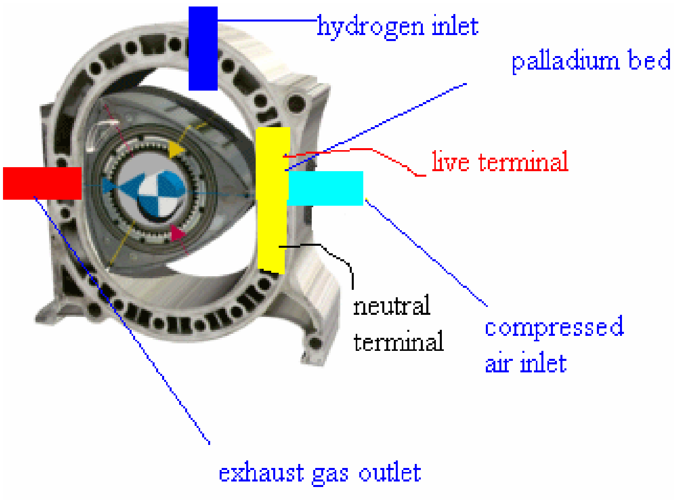
$Y = e\sin 3\alpha + R\sin\alpha$

e = eccentricity

R = rotor center to tip distance

These values help in determining the position of the reference apex and are vital in the design of the engine, as shown in the figures below, many changes have been made to the shell of the Wankel engine, and they are:

- Palladium bed located at the surface of the inside the Wankel engine.
- Compressed air inlet
- Pure hydrogen inlet
- Spark plugs are removed as the cycle is similar to a diesel engine cycle.
- Battery terminals are attached to the palladium bed to attain electrical output



Hydro wankelcell

Conventional Wankel engine

Hydrogen has a low ignition temperature so the standard four stroke engine is prone to pre-detonation and backfiring through the intake ports. This is avoided when the hydrogen and air are injected through two different ports.

There are two processes which are undergone by the hydrogen:

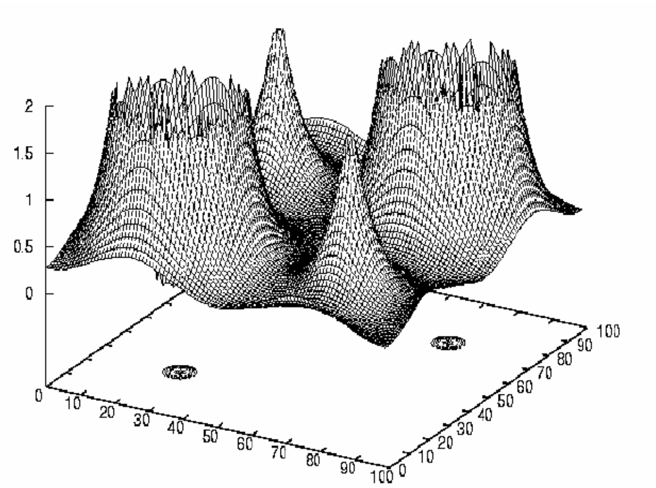
In the first process, pure hydrogen is taken in the intake stroke, which is compressed onto a bed of palladium in the compression stroke. The palladium bed adsorbs the hydrogen forming an interstitial palladium hydride;

this complex compound is basically a mixture of palladium, hydrogen ions and free electrons (PdH, $PdH_{0.5}$ and $PdH_{0.25}$)

The electrochemical reaction can be written as follows: $H_2 = 2\ H^+ + 2\ e^-$ $E^O = 0.41$ volts at NTP

The free electrons which are produced by the occlusion of hydrogen give an electric potential of 0.41 volts per 1 mole of hydrogen. These free electrons can be polarized onto one side forming a negative potential and thus the other side turns into a positive potential. This process can be assumed to be analogous to holes and electrons in semiconductor devices;

hence a current is induced on the surface of the palladium bed, which acts like an intermediate battery which can be used for direct dc volt consumption. A graph plotted for the charge density for PdH, palladium: hydrogen (1:1) on the surface of the palladium is given below. The axes indicate the space of reference for the palladium surface in angstrom (10^{-8})

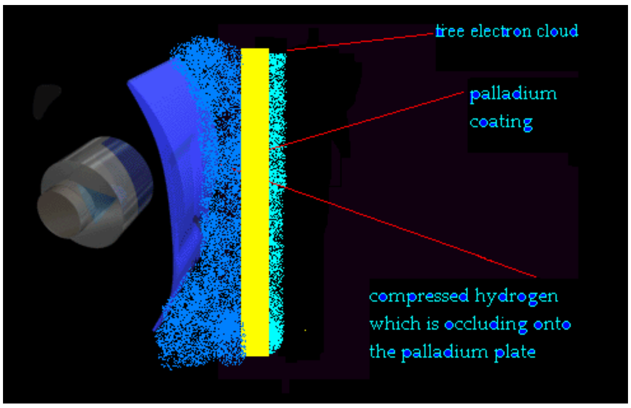


The basic requirement of the engine to be functional as a battery is a minimum of 750 Gms of hydrogen gas occluded in the palladium bed. This can be shown through the following calculation:

{Basic dc voltage requirement = 12 volts

Thus the number of moles of hydrogen required to produce the required voltage = (12/.41) = 29.27 moles = 59 grams of hydrogen (approx)

Assuming a 8% efficiency of the occlusion process



Required amount of hydrogen is nearly 750 grams, is needed for continuous electrical power generation. }

The estimation of 150 Gms might sound large but when the volume of hydrogen required is considered it is around 1.667 m^3 at a time. When compared to a conventional fueled engine tank it is similar to having 1.667 liters of reserve petrol or diesel in a tank.

The wonderful property of palladium hydrogen complex is that it takes in large amounts of hydrogen (about 500 – 800 volumes of hydrogen at NTP conditions) into a relatively small area cross section and hence the palladium bed can be deposited on the walls of the engine. Occlusion of hydrogen decreases with increase in temperature. Thus physical properties of palladium fit perfectly in the compression stroke of an engine as temperature and pressure increase from NTP to a high temperature, hence hydrogen is initially completely occluded and gradually required amounts of hydrogen are given out due to the increase of temperature.

On considering the previously advocated 1.667 m^3, a palladium bed of thickness 0.5cm requires 40 cm^2 (10 cm length and 4cm breadth) which is about 400 grams

theoretically and about 5000$ more per engine. Pure palladium may not be an

economical solution; alloys of palladium, nickel, titanium, vanadium with hydrogen can be used in mixtures to cut down the costs, but this process also has its inherent problems of increasing weight of the engine, improper occlusion etc.

A brief explanation of the design parameters of the Wankel engine are given below:

{The compression ratio inside the Wankel engine is vital as one of the design draw backs, for the engine is its compression ratios being attained,

This is avoided by increasing the (e/R) ratio and by increasing the A_S / R^2 ratio (effect of rounding off the apexes).Unfortunately this has a design limit as the engine tend to be hard to balance by increasing both the values. Optimizations of both the ratios are required.

Compression ratio and equations of power are as follows

$CR = (A_{MAX}/R^2 – (A_S/R^2))/(A_{MIN}/R^2 - (A_S/R^2)) = (\pi \{(e/R)^2 + .33\} - .433\{1-6(e/R)-(3/8)(\beta – \sin \beta)\sin^2\beta \})/ (\pi \{(e/R)^2 + .33\} - .433\{1+6(e/R) -(3/8)(\beta – \sin \beta)\sin^2\beta \}\})$

Displacement volume = $5.196\, w\, R^2(e/R)$

w = rotor width

β =angle of movement of reference apex

Power = displacement (cm^3)* mean effective pressure (KN/cm^2) * speed of the rotor (revolutions/min)/ (60*100)

These equations determine the design of the engine; the β of the Wankel engine has to be aligned with the palladium bed such that the required processes are undergone and maximum efficiency is obtained}

The second process undergone by hydrogen is initiated by the thermodynamics involved in the engine. Heat is released when hydrogen is compressed in the chamber, thus there is a sudden rise of temperature in the compression chamber, this rise in temperature releases hydrogen from the surface of the palladium into the compression chamber. As the pressure has fallen immediately after the compression stroke due to the occlusion process, there is an erratic rise of pressure in the matter of micro seconds due to the release of hydrogen from the palladium surface due to rise in temperature.

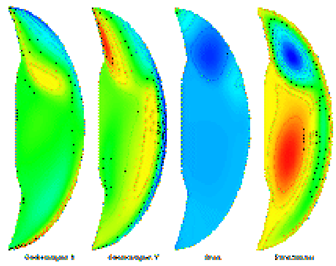
REQUIREMENT OF COMPRESSED AIR:

The compression chamber is exposed to compressed air at room temperature; this process is similar to the process of super charging where the air is compressed before mixing with the fuel, this process is required for various reasons which are as follows:

The pressure inside the compression chamber is much higher than the atmospheric pressure (for example , it can reach up to 20 bar , depending upon the compression ratio inside the compression chamber)

The hydrogen inside the compression chamber is at a high temperature, hence for starting the ignition of the engine no spark plug is required similar to a diesel engine.

As the hydrogen is at a much higher temperature then the compressed air; the combustion process is started due to the disparity in temperatures. Flame propagates from the inlet port of the compressed air as shown in the ANSYS images (with false coloring, indicating various processes of importance of the engine)



The green portion on the left most picture indicates that the hydrogen which is already pumped in after suction stroke, there is no change in temperature inside the

chamber, the blue ring on the outside indicates a pressure decrease, thus leading to a temperature decrease at the very edge due to the occlusion process of the hydrogen, initiated on the palladium bed.

The red patch on the top left corner indicates the increase of temperature due to the friction between hydrogen and the apex, as the compression process of hydrogen has started.

The yellow portions indicate a mild increase of temperature due to the fluid properties (compressibility) of hydrogen.

The next picture which is completely blue indicates a sudden dip in temperature this is due to the complete adsorption of the fuel by the palladium bed reducing the inner pressure and hence the temperature, the light blue areas on the right indicate a mild increase of temperature due to a small amount of heat released during occlusion processes, the light blue areas on the top are due to residual pressures created due to the friction between the hydrogen and the apex.

The right most of the pictures indicates the combustion stroke where the flame propagation (red) is clearly indicated and the areas where hydrogen tends to burn a little late (blue), the elliptical nature of the processes is due to the boundary layer formed inside the cylinder.

Thus the plot gives the designer an idea of the amount of temperature, pressure and places where flame propagates during various strokes of the engine.

EXPERIMENTATION:

Flame propagation inside the combustion chamber needs to be better explained and ways of avoiding the usage of compressed air as a combustion initiator have to be devised. There is a need for a better understanding of the palladium occlusion processes are issues like variable resitivity on the palladium bed, availability of cost effective materials and mass production of hydrogen are large road blocks. Elaborate research and prototype testing is to be done on the mentioned topics in the near future.

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