The Resurgence of Ball-Piston Engine: A highly efficient machine

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Abstract - *In the course duration of time, machine designing is molding itself manifested towards unambiguous and easier technology. This counts on updated versions of steering, engines, transmissions, etcetera. The paper mainly focuses on the researches done and advancements made on the Wolfhart engine. It is an idea of Wolfhart Williamczik, a German Physicist, to compensate problems of the Wankel Engine in the 19th century. Some inertial loads caused a dramatic failure in the design which led to the necessity to create piston-cylinder engines. But individual researches have been started in recent times to restart the era of ball piston engines as they offer reduced space occupancy and less moving part-count, besides the emerging technology of eco-friendly engines. Researches are being carried out across the world in countries Germany, the USA, Russia, Japan etcetera. Low leakage of fuel and lubrication can be achieved without rings by using small clearance on ball piston mountings. The foremost requirement for any machine is high efficiency which is being offered by ball piston arrangement results in a crowning dynamic balance to the engine.*

Key Words: **Wolfhart engine, Wankel Engine, Reduced space occupancy, less-moving part count, high efficiency, dynamic balance.**

1.INTRODUCTION

In the present dynamic world, automobile engineering and part designing are given an heir as these are contributing their services from base to border of present needs. So, the world is looking forward to smarter and faster machines. The concept of rotary engines from the past is now being researched to achieve this. The main parts that make us spotlight on rotary engines are their less space occupancy and reduction of inertial loads. Several rotary engines like Wankel, Hanes, Wolfhart, and recently Rand cam engines have been developed to date and every engine had their unique features as well as failures. The Wankel rotary engine can be named as one of the most successful rotary engines but faced a backlash with sealing problems. Apart from the higher losses and hardware complexity, less reciprocating mass in the areas of pumps and compressors is generally a challenging task in positive displacement vehicles that can be achieved effectively through lobes, gears, and screw compressors. But recent efforts and researches are being made to attain an updated version of rotary engines, that is, The Concept of Ball Piston Engines, which offers many advantages than the current trend of piston-cylinder engines. The concepts of design and key features, technical challenges, pros, and cons etcetera are discussed throughout the paper.

2. THE DESIGN CONCEPT

A rotary engine can be of 4-stroke, 8-stroke, or more advanced 12-stroke. Till now 4stroke is a clear concept and 8-stroke is still under research and design in countries like Germany and Tokyo. The new design is supposed to offer many advantages like very low friction, heat losses, and design simplicity etcetera. The parts of the ball piston engine can be observed in fig1.

In a brief, the basis of the design is ball pistons rolling on eccentric track with balls exerting tangential forces on the cylinder walls which turn the rotor. Useful power is collected at the output shaft.

1. Rotary Piston 2. Rotary Cylinder 3. Hosing 4. Spherical Combustion Chamber 6. Inlet 7. Exhaust 8. Air Stroke 9. Rotary cooling fan 10. Air Outlet 11. Key Way 12. Partition Wall 15. Piston Ball Bearing 16. Working Chamber

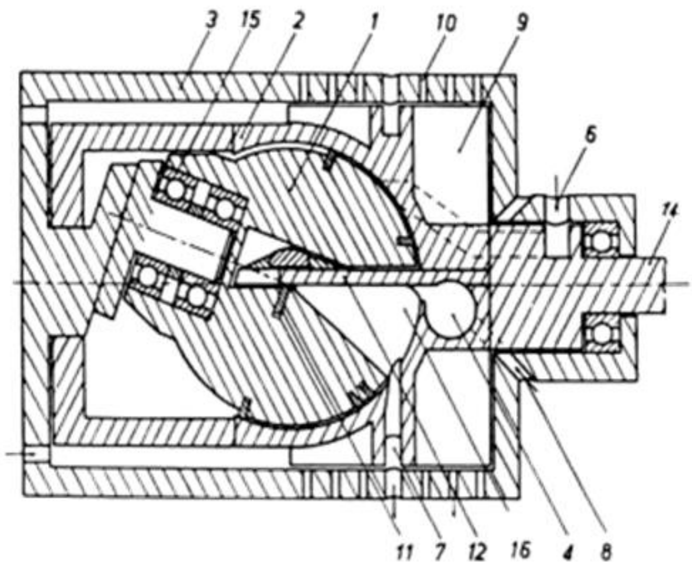

Fig – 1 : Cross Section of a ball piston engine. [1]

3. MODE OF WORKING

As the moving parts are in rotary motion about a central axis, the considering parameter is the angle of rotation. As discussed above Wolfhart engines are 4-stroke engines.

3.1 Intake Stroke (0-90°)

The ball piston initiating from Top Dead Centre (TDC) moves radially outward from 0°. This allows the stator to open the intake passage that pulls the fuel air-mixture into the cylinder. That mixture is known as charge. The outward motion comes up to 90° and then closes the intake passage.

3.2 Compression Stroke (90° - 180°)

The new charge from the intake phase is compressed up to a sufficient rate and the ball reverses its radial direction for the next right phase. This allows for increasing the pressure and reduction in the volume of charge.

3.3 Ignition Stroke (180° - 270°)

This stroke is important of the all the strokes as the desired output is generated here. The compressed charge is now subjected to an electric spark of nearly 10,000 W with the help of a spark plug. As the charge is already holding high pressure, this ignition pushes the ball piston radially upwards to the next 90°. Now, the ball, as a reaction, pushes the cylinder wall tangentially due to the slope arranged for the eccentric ball track. This now allows the ball to move outward radially. Output power is generated due to the torque produced on the rotor due to the tangential force.

3.4 Exhaust Stroke (270° - 360°)

The burnt charge that needs to be exhausted is sent out through this phase. The uncovered part of the cylinder allows access to restart the cycle.

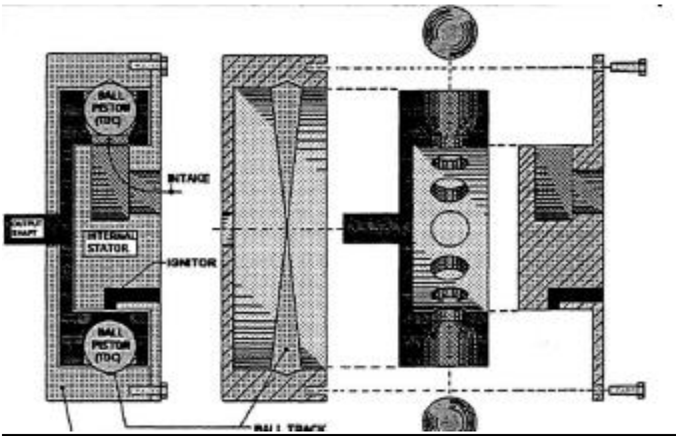

Fig – 2: Side Sectional View of ball piston arrangement [1].

4. DESIGN FEATURES

Present ball piston engines which are a type of combustion engine works based on 4-stroke Otto cycle. Some changes can be made which offer maximum efficiency and emission control. Side sectional view of the ball piston arrangement is seen in fig.2.

4.1 Moving Parts

A piston, camshaft, crankshaft, connecting rod need to be moved in a traditional piston-cylinder arrangement which automatically demands much clearance and space. This can be reduced by lowering the moving part count and just moving a ball piston and a track. No valve train losses add an advantage to promote ball piston arrangement.

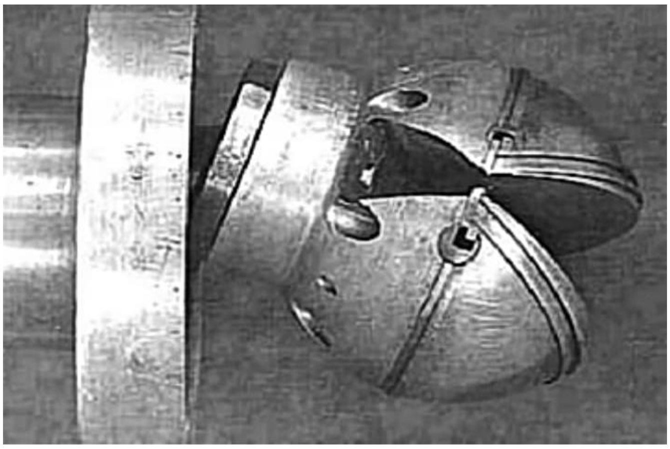

Fig – 3: A ball piston model [1]

4.2 Hardware Geometry

The Wolfhart engine needs a simple machine geometry than other engines. This allows us to understand the operation and easy repair. As the parts moving in rotary motion, the base parameter is the angle of rotation.

4.3 Friction Terms

Fast and continuous motion generally produces a higher friction value that leads to wear and failure of hardware. Scientific results proved that sliding friction can be minimized by using rolling components. Rolling ball piston overcomes this friction challenge with ease, with proper lubrication at contact surfaces. In the stator area, it is a hydrostatic type. So, friction is automatically low at that site.

5. CHALLENGES AND FAILURES

Many tests are made theoretically and practically to find out troubles and design failures. Subscale testing is the standard testing for any machinery.

The main problem that will be faced by any moving machine is insulation and leakage. Leakage may occur at the stroke arena, more specifically at low speeds. Due to low clearance area and high-pressure difference, in combustion stroke flow will be either blocked or leaked. The chocking levels must be maintained at allowable limits otherwise the efficiency of the engine gets affected.

Coming to friction losses, calculations show that the magnitude of effective friction coefficient, and relative sliding speed affects the engine friction coefficient and relative sliding speed effects the engine performance regarding wear and tear. Theoretically, friction coefficient 0.1 or less gives maximum efficiency and more functioning time for the engine. Sensitive experiments are needed for achieving favorable practical output. While calculating theoretically, it must be considered that the machine is working in no lubrication condition besides working fluid. This gives results for the most feasible compressor and pumps application. Care must be taken in the process of lubrication. If high lubrication is done, it would lead to slipping and change the theoretical calculation results.

In the Wolfhart engines that were used in the past, they used a duel contact track with a maximum rolling radius at TDC. This was made eventually without any engineering calculations. It caused failure as it is needed to be changed in a sinusoidal manner to a small rolling radius at BDC. This led to the impact of additional frictional forces that reduced the output power from the combustion chamber.

6. TROUBLESHOOT AND ADVANCEMENTS

By simple chocking experiments and using of standard material for ball piston, pressure regulation and leakage lock can be achieved. For this, leakage modeling which is based on simple orifice flow (neglect ball spin) with the chocked flow when subjected to high pressure is studied. Specific power curves for constant ball spin rate and optimal track cases gave a result of no leakage and thermal losses.

A new design is being built (known as novel design) to eliminate inertial forces on every ball that contributes to friction. During the in and out motion of the ball, due to the net tangential inertial forces, friction is formed at the contact point and the walls. But the calculations gave a result that, if the ball rolling radius is reduced in a prescribed manner using a narrow dual contact track, net tangential inertial forces can be eliminated.

Now the ball track is being designed in such a way that the ball rolls around the track in corresponding to the rotor with constant rotation rate. Now, if this condition can be achieved practically from laws of motion.

To overcome the ball fatigue damage at higher speeds, the internal stresses in the balls must be perfectly balanced. It can be achieved by regulating the motion of all the ball along its axis and radial axis with ball track (compressive). Proper material selection supports the negation of friction losses. For example, a silicon nitride ball piston has a coefficient of friction of 0.075 ± 0.03 at no-load condition.

7. CONCLUSIONS

The terms of design and working shows that the ball piston engine can achieve higher efficiency and does the troubleshooting of piston-cylinder internal combustion engines are facing. Differences and advantages relative to traditional piston internal combustion engines are discussed. Conventional carburation or induction and exhaust systems are being developed efficiently to increase the life span of the machine. Experimentally proved results regarding the Wolfhart engine are discussed and a new idea that may increase its performance characteristics is shared. If the engine is fabricated with all the design features and experimentally achieved values, the concept of Ball Piston holds an immediate promise of high efficiency, and low cost probably with a greater life span.

REFERENCES

[1] German patent specification 2519911 and GDR patent 113*88
[2] Rory R Davis, "M. The concept of ball piston engine – A new concept in higher efficiency power machines", SAE Technical paper series,1997.
[3] Heywood J.B, "Internal combustion engine fundamentals", McGraw- Hill, New York.
[4] Wiley Online Library, "Rotary Piston Symposium."
[5] www.animatedsoftware.com - 1984