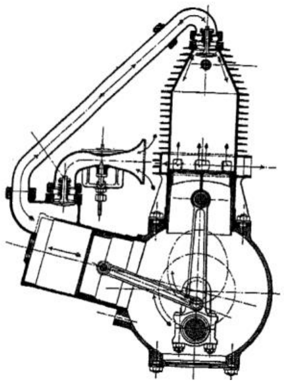
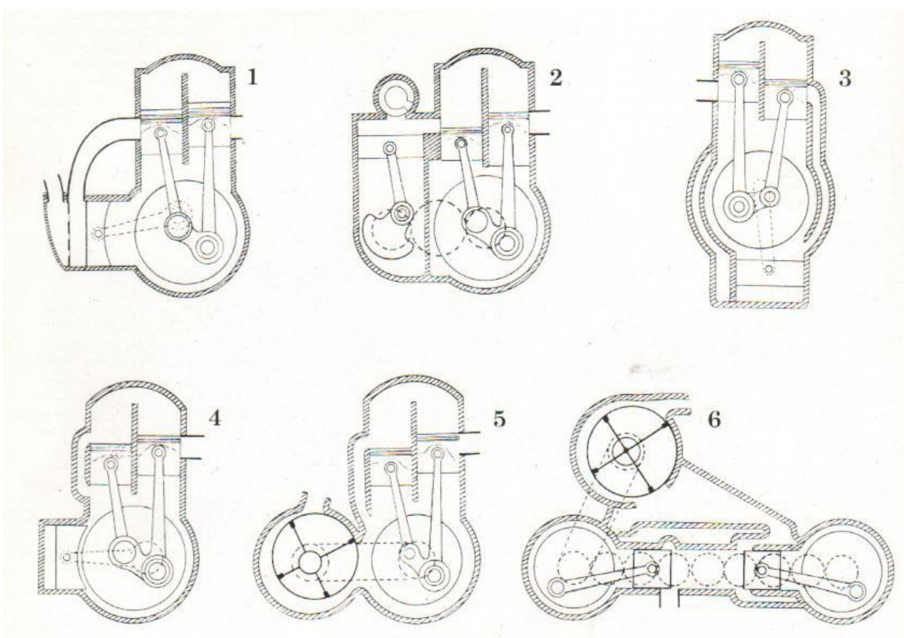
High Power Two Stroke Design Part 1

Two stroke engines have fascinated engineers since they were invented by Dugald Clerk in 1881.



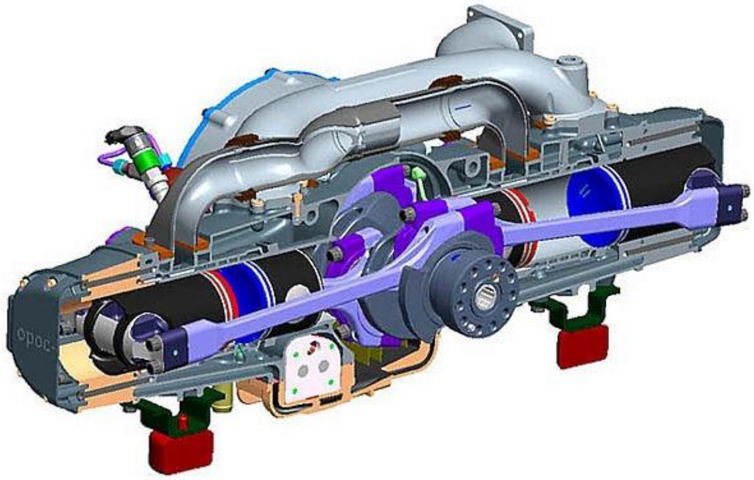
Clerk's Engine

The promise of one power stroke per revolution was counter acted by the need to charge the cylinder with an outside system. Many elaborate schemes have been devised to solve this problem. DKW motorcycle engines illustrate successful, but complex, approaches to the problem.



DKW Engines

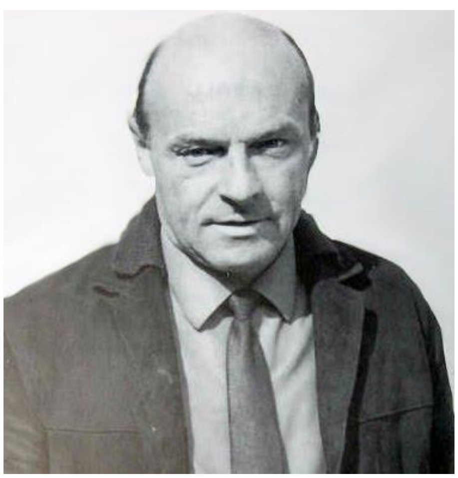
Even today complex new two strokes are being introduced.



Eco Motors Opposed Piston Engine

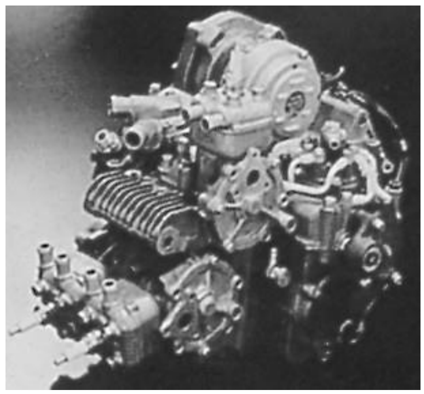
There is another way. In 1889 Joseph Day invented a valveless, two stroke engine that used the crankcase as the scavenging pump This engine was largely overlooked for high power and was used where low cost, light weight, and simplicity were critical. Outboard engines, chain saws, and inexpensive motorcycles were some of the main applications. However, in the ruins of East Germany after World War II, this simple engine was reborn.

The East German government was interested in proving the superiority of their sportsmen and, in 1953, promoted Walter Kaaden to head of the racing department of MZ (Motorradwerk Zschopau) motorcycles in East Germany.



Walter Kaaden

Kaaden was forced to build simple engines because his factory had been looted and only had very limited resources. However, he had the rich, German two stroke history (his father was a chauffeur at the DKW factory) and he had worked as an engineer on the V 1 cruise missile. The government "suggested" that Daniel Zimmerman share his disk valve design and Kaaden applied it along with the scavenging system developed in 1926 by Adolf Schnürle to the crankcase scavenged engine. He experimented with the tuned exhaust system developed in 1951 by Erich Wolf at DKW. Kaaden understood the wave nature of two strokes, and he used oscilloscopes to study the wave action in the exhaust. In 1954 he had simple crankcase pump induction engines producing 100 horsepower per liter. By 1961 his engines were producing twice that power. That year Ernst Degner, the champion factory rider, defected to the West and took the MZ engine designs to Suzuki. He won the 50 cc world championship the next year and the Japanese two strokes dominated motorcycle racing for the rest of the decade. Before multi cylinder 50 cc engines were banned in 1969, Suzuki developed a three cylinder, 50 cc engine that produced nearly 20 hp.



Suzuki 50 cc Engine

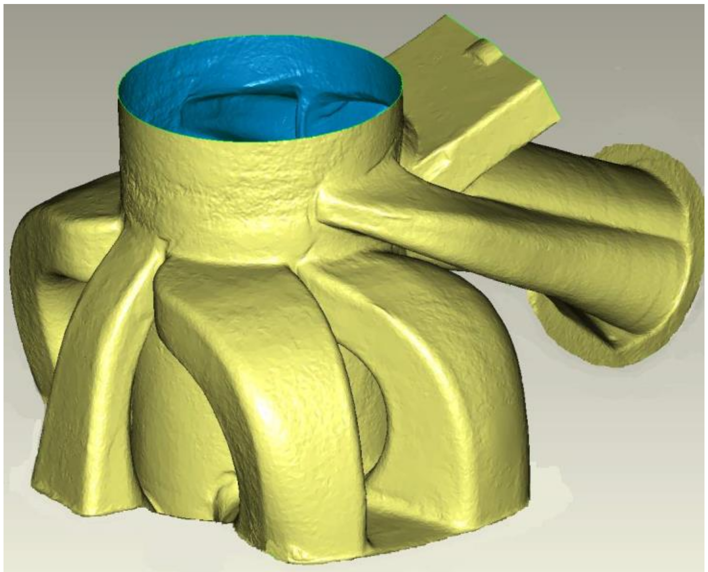
Bill Wisniewski is generally attributed with bringing this technology to model engines. In 1964 he brought his Theobald-Wisnewski Association "wart" engine (from the bump on the casting for the boost port) to the FAI control line speed championships and won. In 1966, he added the tuned pipe, and the Americans were 1, 2, 3 with this technology. Bill gave a talk at the event explaining the details of his engine and pipe. He published a pipe design article in the March 1967 issue of Model Airplane News. Bill's Pink Ladies dominated control line speed events for years. He was responsible for the design of many of K&B's high performance engines and worked there from 1961 almost until his death in 2007. The Russians petitioned the FAI to make tuned exhaust systems illegal, but they, along with Schnürle porting, are still a design feature of most high performance model engines.

Bill Wisniewski 1966

What distinguishes the modern, high power small two stroke? The first requirement of a high rpm engine is sufficient flow area in the intake, transfer, and exhaust ports. Empirical methods have identified the time area required to generate this flow for a particular power at a given rpm. Time area is the "average" open time and area of a port that determines how much fluid can flow through it in an engine cycle. The program I use, Engine Mod2T, calculates this from the input data. Getting enough blow down area is tough. The blow down period is the time between exhaust port opening and transfer port opening. This period partially exhausts the cylinder and, more importantly, creates a powerful exhaust pulse. Since the maximum width of an exhaust port is around 70% of the cylinder bore, divided and triple exhaust ports were developed. The remaining wall area is used for the transfer ports.

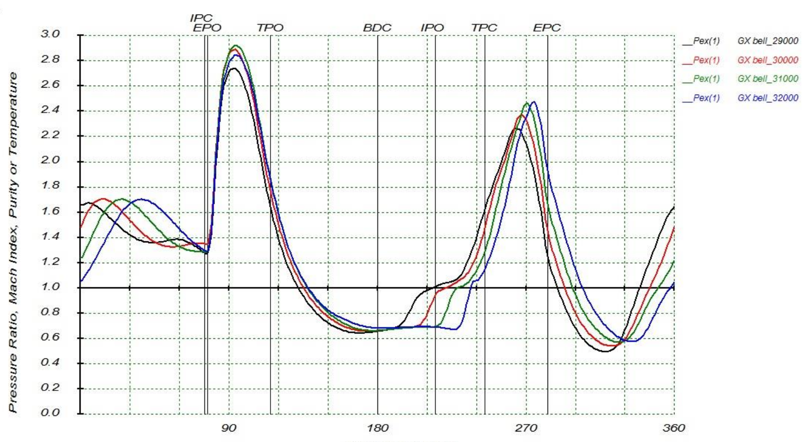

Aprilia Ports

The second requirement is good scavenging of the cylinder. In a four stroke the piston forces the combustion products out the exhaust during a full upstroke of the piston. In a two stroke this process has less than half the time at the same rpm as a four stroke and is accomplished by the incoming air. A two stroke's power is a sensitive measure of its scavenging efficiency. Experimenting with transfer port layouts and angles has still not completely solved scavenging issues in the Schnürle style scavenging system. However, most current high power engines use four transfer ports with a small single rear boost port. The transfer passages need to be gently curved for good directional control of the incoming mixture. The up angles on the transfers are partly determined by the bore/stroke ratio and piston speed. The goal is to have the flows collide just above the piston to create a rising column that doesn't mix with the combustion products. This column needs to stay along the back side of the cylinder away from the exhaust to avoid too much loss out the exhaust port. A very interesting series of visualizations of this process in a piston port non piped engine can be found at: http://aam.mathematik.uni-freiburg.de/IAM/homepages/trescher/2StrokeEngine/movie/2StrokeEngine_MPEG1.mpg



Aprilia Transfer Passages

The third requirement is a tuned exhaust system that creates a low pressure in the cylinder during the time the transfers are open and a high pressure pulse after they close. The low pressure pulse helps evacuate the cylinder. It also encourages flow out of the crankcase through the transfers and into the crankcase through the intake. The high pressure pulse returns fresh mixture that has flowed out the exhaust port and supercharges the cylinder. The tuned pipe is responsible for more of the simple two stroke's power than any other part of the engine. Notice in the graph below that this supercharge amounts to 2.4 atmospheres absolute or a boost pressure of 20 psi above atmospheric pressure.



Pressures at the Exhaust Port

Today the Aprilia 125 represents the peak of modern small two stroke development. This engine develops 54 horsepower at the transmission output shaft. That's over 400 horsepower per liter, twice what Kaden's engines produced. From the lessons learned in their 125 cc race engine program, engineer Jan Thiel predicted that a two cylinder 50 cc engine could develop 39 horsepower at 23,000 rpm. That would be over 19 horsepower from a 25cc racing engine, about three times the power developed by the industrial type engines now used in model boat racing.

Is this the best that can be done? What old and new ideas promise to give two strokes even more power? Part 2 will explore the future.