History of compressors

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Outline of the Presentation

- Earliest history
- First steps to the mechanical compressors
- History of the compressors control

Earliest history

The first air compressors weren't machines, but human lungs: Primitive people blew on cinders to create a fire. We now know that healthy lungs can exert pressure of 0.02 to 0.08 bar

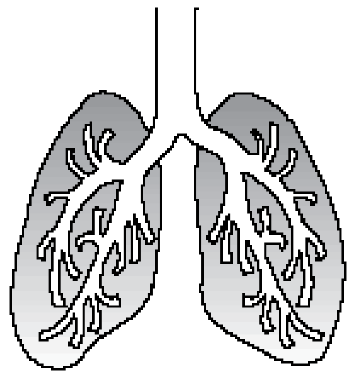


Figure: The human air-compressor

Earliest history

As people began to melt metals such as gold, copper, tin and lead, higher temperatures were needed, and a more powerful compressor was required.

Figure: The usage of the compressed air

Earliest history

Egyptian and Sumerian metallurgists used the wind, then blowpipes for their work.
The first mechanical compressor, the hand-operated bellows, emerged soon after, and in 1500 B.C. the more efficient foot bellows came into use.

Figure: The usage of the compressed air

Earliest history

Figure: Ctesibius of Alexandria (c. 285-222 BC)

The discovery of the elasticity of air is attributed to Ctesibius, as is the invention of several devices using compressed air, including **force pumps** and an **air-powered catapult. Ctesibius' writings have not survived**, and his inventions are known only from references to them by Vitruvius and Hero of Alexandria, **but he laid the foundations for the engineering tradition that culminated in the works of Hero of Alexandria and of Philo of Byzantium.**

Earliest history

Figure: Hero (or Heron) of Alexandria 10 AD)

Heron designed an automatic temple door opener, which used heat and pneumatics to open a set of temple doors.

Earliest history

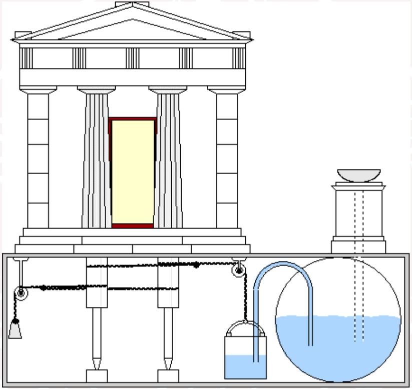


Figure: Hero (or Heron) of Alexandria 10 AD)

Earliest history

Movements based on the wheel with the blades in some naturally fluid area (like wind or water).

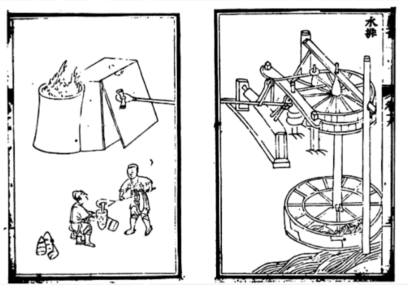


Figure: Water-powered blowing- engine of the 13-th century. China.

First steps to the mechanical compressors

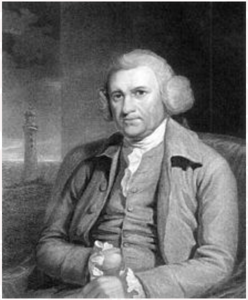


Figure: John Smeaton. Born 8 June 1724 (1724-06-08), England

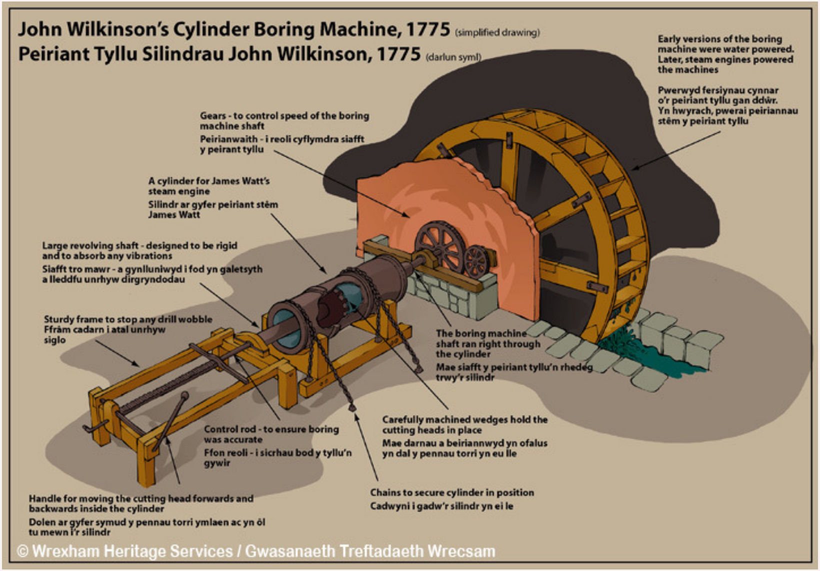
In 1762, John Smeaton, the first professional engineer, built a water wheel-driven blowing cylinder that began to replace the bellows.

First steps to the mechanical compressors

Figure: John Wilkinson. Born 1728, England

Inventor John Wilkinson introduced an efficient blasting machine in England in 1776; **the machine was an early prototype for all mechanical compressors.**

First steps to the mechanical compressors



John Wilkinson's Cylinder Boring Machine, 1775 (simplified drawing)

Peiriant Tyllu Silindrau John Wilkinson, 1775 (darlun syml)

Early versions of the boring machine were water powered. Later, steam engines powered the machines

Pwerwyd fersiynau cynnar o'r peiriant tyllu gan ddŵr. Yn hwyrach, pwerai peiriannau stêm y peiriant tyllu

Gears - to control speed of the boring machine shaft

Peirianwaith - i reoli cyflymdra siafft y peirant tyllu

A cylinder for James Watt's steam engine

Silindr ar gyfer peiriant stêm James Watt

Large revolving shaft - designed to be rigid and to absorb any vibrations

Siafft tro mawr - a gynlluniwyd i fod yn galetsyth a lleddfu unrhyw dirgryndodau

Sturdy frame to stop any drill wobble

Ffrâm cadarn i atal unrhyw siglo

The boring machine shaft ran right through the cylinder

Mae siafft y peiriant tyllu'n rhedeg trwy'r silindr

Control rod - to ensure boring was accurate

Ffon reoli - i sicrhau bod y tyllu'n gywir

Carefully machined wedges hold the cutting heads in place

Mae darnau a beiriannwyd yn ofalus yn dal y pennau torri yn eu lle

Handle for moving the cutting head forwards and backwards inside the cylinder

Dolen ar gyfer symud y pennau torri ymlaen ac yn ôl tu mewn i'r silindr

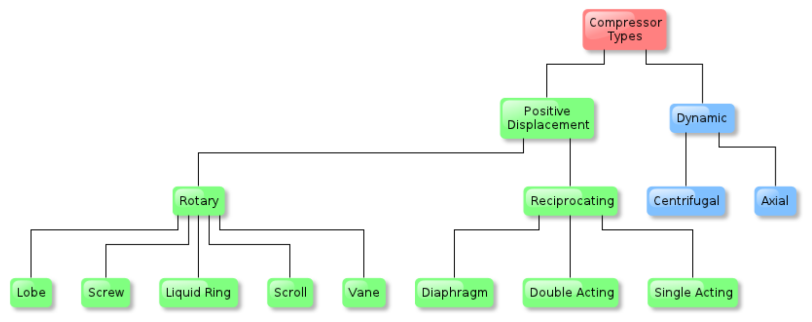
Chains to secure cylinder in position

Cadwyni i gadw'r silindr yn ei le

First steps to the mechanical compressors

The basic principle is the same and without the primitive air compressors, civilization would not have evolved as fast it has. It wasn't until later in history that it became possible to compress air using mechanical methods. **In the past, only human and animal power was possible to power crude air compressors and this severely limited the utility of these primitive devices. With the industrial revolution, the mechanical compressor was born.** Engines running from steam power became the first method to power these compressors. One of the first uses of a steam powered pneumatic-compressor was in underwater diving equipment

The main types of gas compressors



Compressor Types

Positive Displacement

Dynamic

Rotary

Reciprocating

Centrifugal

Axial

Lobe

Screw

Liquid Ring

Scroll

Vane

Diaphragm

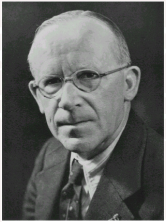
Double Acting

Single Acting

Axial gas compressors

Early axial compressors offered poor efficiency, so poor that in the early 1920s a **number of papers claimed that a practical jet engine would be impossible to construct.**

Axial gas compressors

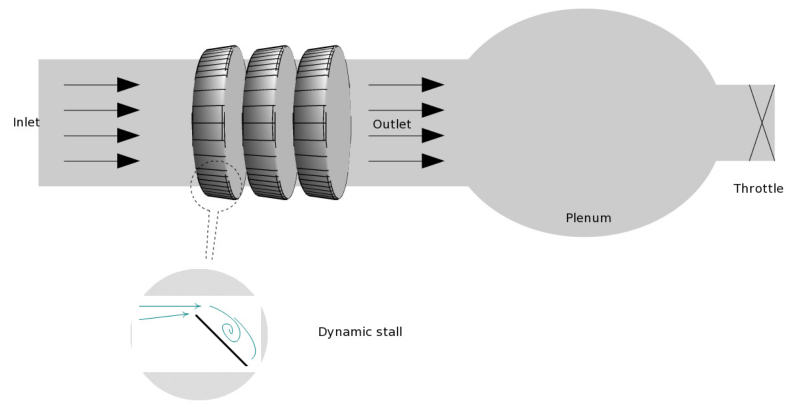


Alan Arnold Griffith FRS.
(Reproduced with permission from
the Royal Society.)

Things changed after **A. A. Griffith** published a seminal paper in 1926, noting that the reason for the poor performance was that existing compressors used flat blades and were essentially "flying stalled". He showed that the use of airfoils instead of the flat blades would increase efficiency to the point where a practical jet engine was a real possibility. He concluded the paper with a basic diagram of such an engine, which included a second turbine that was used to power a propeller.

Three-state Moore-Greitzer compressor model

Axial compressors are rotating, airfoil-based compressors in which the working fluid principally flows parallel to the axis of rotation.



Problem definition

Difficulties:

- unstable dynamics
- non-globally Lipschitz (cubic) nonlinearity
- not stabilizable with static output feedback

Three-state Moore-Greitzer compressor model

$$\begin{aligned}
\frac{d}{dt}\phi &= -\psi + \frac{3}{2}\phi + \frac{1-(1+\phi)^3}{2} - 3R(1+\phi) \\
\frac{d}{dt}\psi &= \frac{1}{\beta^2}(\phi - u) \\
\frac{d}{dt}R &= -\sigma R^2 - \sigma R(2\phi + \phi^2), \; R \geq 0 \\
y &= \psi
\end{aligned} \tag{1}$$

here ϕ and ψ have the physical meaning being deviations of the averaged flow and the pressure from their nominal mean values, respectively.

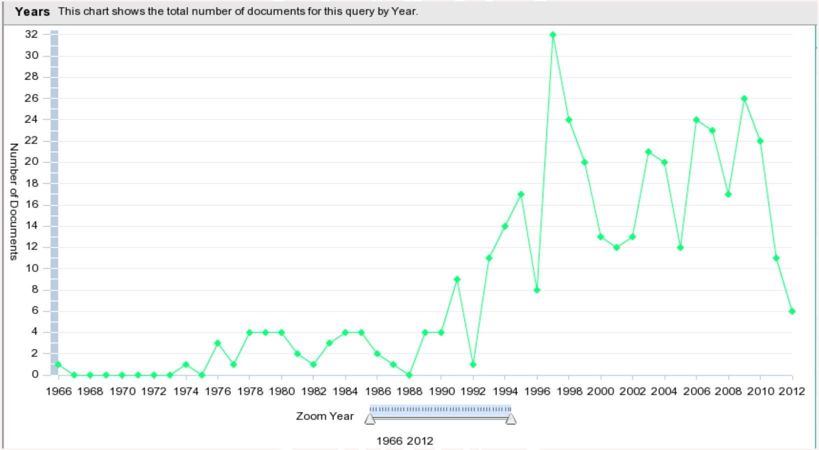
The stall R cannot be measured and used for feedback design.

Preliminaries. Previous Research

Previous Research:

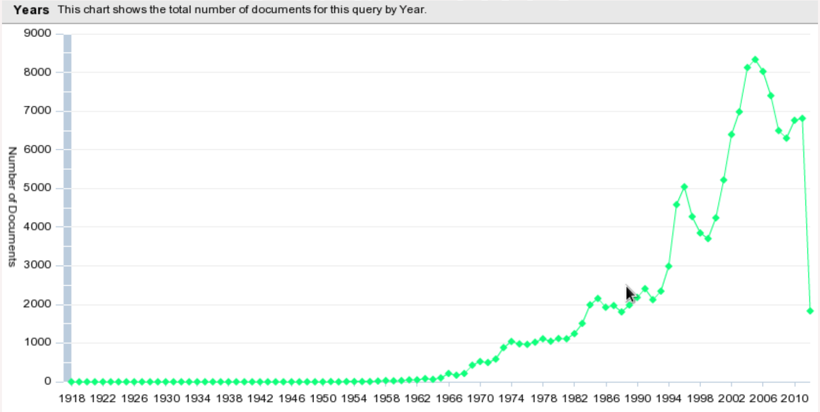
- F.K.Moore, and, E.M.Greitzer
    - A theory of post-stall transients in axial compressor systems. 1986
    - Surge and rotating stall in axial flow compressors 1976
- J.D. Paduano
    - Compression system stability and active control. 2001
- M. Arcak and P.V. Kokotovic
    - Nonlinear observers: a circle criterion design and robustness analysis. 2001
- A.S. Shiriaev
    - Functional analysis of the constraints and conditions.
- J.T. Gravdahl
    - Drive torque actuation in active surge control of centrifugal compressors

Previous Research



Years This chart shows the total number of documents for this query by Year.

Possibilities of computer technology



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Futute of compressors control

Output Feedback Control

Thank YOU!