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Research Article

Design and Analysis of Major Parts of Reciprocating Air Compressor using Advance CAE Tools

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Abstract

This research paper presents a comprehensive investigation into the redesign of compressor pistons, a crucial component in various industrial compression systems. The study aims to address longstanding challenges associated with conventional piston designs, seeking to optimize performance, efficiency, and overall reliability. Through a systematic approach, the research explores modifications to piston geometry, material composition, and surface treatments, considering the intricate interplay of factors influencing compressor functionality.

The redesign focuses on minimizing frictional losses, a major source of inefficiency in traditional piston configurations. Advanced materials, such as high-strength alloys and composite structures, are evaluated for their potential to enhance durability and reduce wear over extended operational lifetimes. Additionally, innovative surface coatings are explored to improve heat dissipation, mitigating thermal stresses and contributing to overall system efficiency.

Experimental validation of the proposed redesign is conducted using state-of-the-art testing methodologies, including performance metrics, heat distribution analysis, and wear assessments. The results showcase promising advancements, demonstrating a notable reduction in energy consumption and enhanced operational stability. These findings not only contribute to the fundamental understanding of compressor piston dynamics but also offer practical insights for the design and implementation of more efficient pneumatic systems across a range of industrial applications. The implications of this research extend to the broader pursuit of sustainable engineering solutions, emphasizing the importance of continuous innovation in optimizing mechanical components for increased energy efficiency and reduced environmental impact.

Keywords: Piston; Compressor; Piston Ring; Piston Rib; Thermal Analysis; Static Analysis

Introduction

Compressors, as thermodynamic devices, consume power to raise the pressure of gases and vapors from low to high. The second law of thermodynamics dictates that external sources like prime movers, electric motors, or internal combustion engines must do work on the gas for this compression. Work done by the compressor faces losses due to friction, radiation, cooling of the fluid used to cool the compressor, and delivering gas at high pressure [1]. In essence, the compressor draws gas at low pressure, compresses it, and delivers it to a receiver for storage or transportation through pipelines. Smaller reciprocating compressors (5 to 30 horsepower) are common in automotive settings, while larger ones (over 1000 hp) are prevalent in industrial and petroleum applications. Multi-stage compressors often incorporate intercoolers, heat exchangers that enhance efficiency by removing compression heat between stages. To counter the temperature, increase during compression, after-coolers are employed after the final stage.

Mostly, there are two types of compressors [2].

- High Power-Top Dead Centre (HP-TDC)
- High Power-Bottom Dead Centre (HP-BDC)

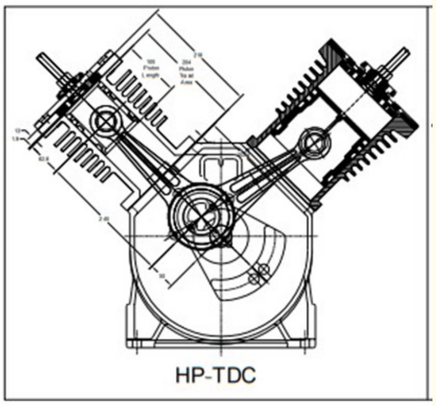

Figure 1: HP-TDC.

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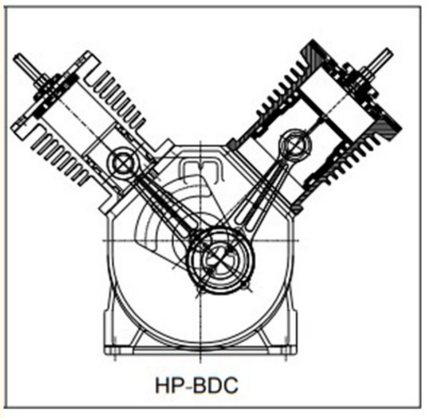

Figure 2: HP-BDC.

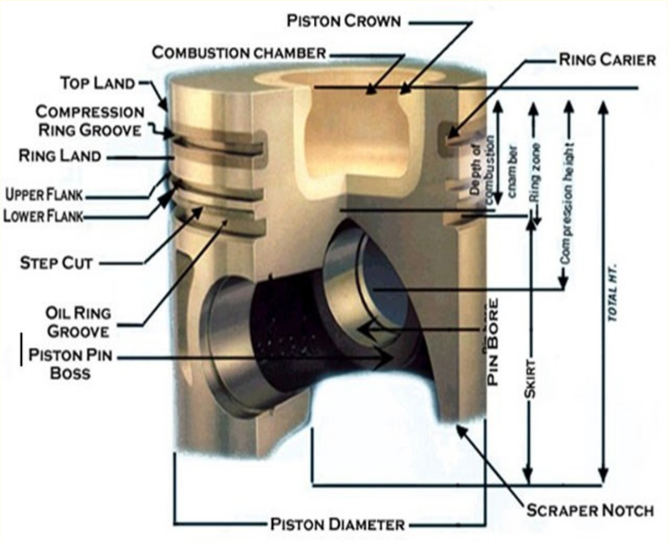

Figure 3: Piston Part [8].

The piston plays a vital role in compressors, featuring a reciprocating motion that transforms heat energy into mechanical power. Operating within a cylinder during power generation, the piston moves up and down to withstand the expansion of gases and transmit this force to the crankshaft. This transfer of explosive force to the crankshaft induces rotation. Equipped with rings for sealing against the cylinder wall, the piston's design complexity is notable.

Problem statement

"Re-Design/Re-Validation of 140 mm Diameter, Piston with Piston Ring and Guide Ring Design for Reciprocating type air compressor".

Below are the layouts and parameters used for the Piston and Piston Ring and Guide Ring for reciprocating compressors.

The above set of instructions are parameters followed while designing the Piston and Piston Ring and Guide Ring to ensure the required output is Obtain.

Project Name:	Design and Analysis of Major Parts of Reciprocating Air Compressor using Advance CAE tools (Re-Design of 140 mm Día. Piston with Piston Ring & Guide Ring Design for Reciprocatingtype air compressor)		
Compressor Specification Compressor Technology: Reciprocating Compressor Type of Cooling: Air Cooled Type of Lubrication: 100 % Oil-Free / Oil-Less No of Cylinder: Two No of Stage: Two Cylinder LP (1st Stage) 140 mm Cylinder HP (2nd Stage) 90 mm Stock: 100 mm Compressor Speed: 660 RPM Piston Displacement capacity: 35.9 cfm (1016 LMP) Design Pressure: 10 bar Electric Power Require: 10 HP			
Sr	Particular	Size/Specification	Remark
1.	Cylinder Bore Día.	140 mm	
2.	Piston Travel Area (Stock)	100 mm	
3.	Piston Pin Diameter	30 mm	
4.	Other Details	As per dwg.	

Table 1

Below are Given Dimension for Piston Re-Design and make it as they are able to absorb10 bar Pressure.

Approaches

Firstly, we made 3D-model in Solidwork (CAD-Software) for doing different types of analysis (Thermal analysis and Static analysis) at 10 bar pressure. We wanted to check that whether the pressure would be absorbed by a piston or not.

We have generated a test scenario for examination, involving both thermal analysis and static analysis. Subsequently, we exerted a pressure of 10 bars on the upper surface of the piston, as illustrated in the accompanying Figure 7 and 8.

After, we got some tremendous result of analysis at 10 bar external pressure at the top of the piston. Which are shown below figure 9 and 10.

Methods

As per above analysis we are able to say that piston cannot able to absorb 10 bar pressure so now my actual role is gone start, so

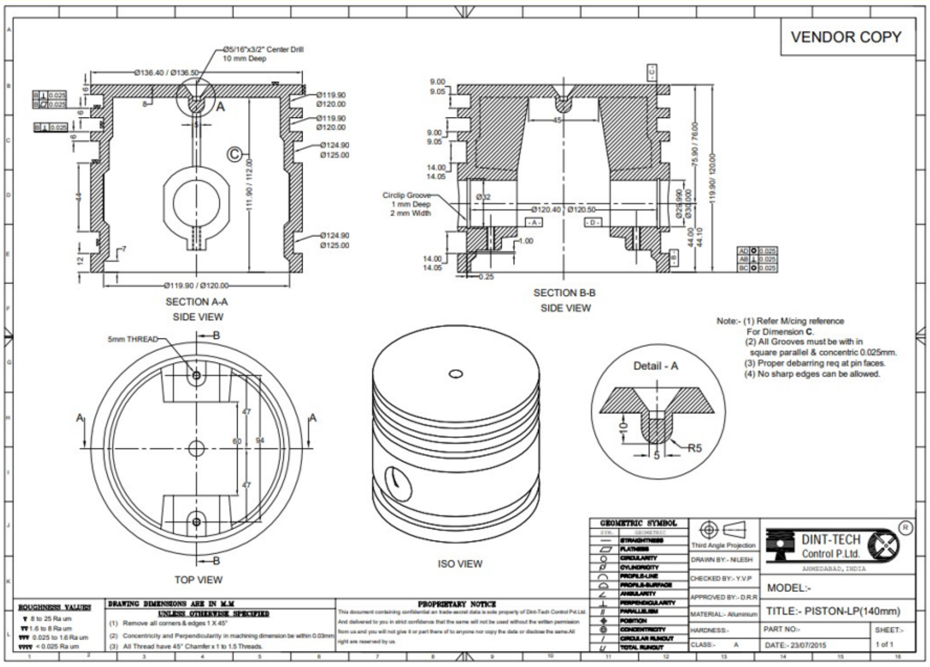

Figure 4: Arthrography and Isometric view of Piston with Dimension.

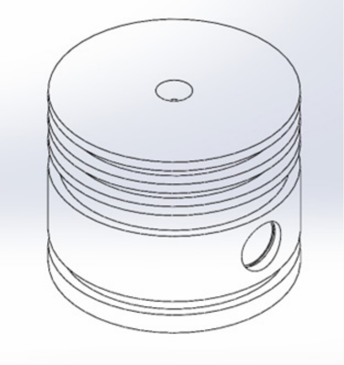

Figure 5: Isometric View.

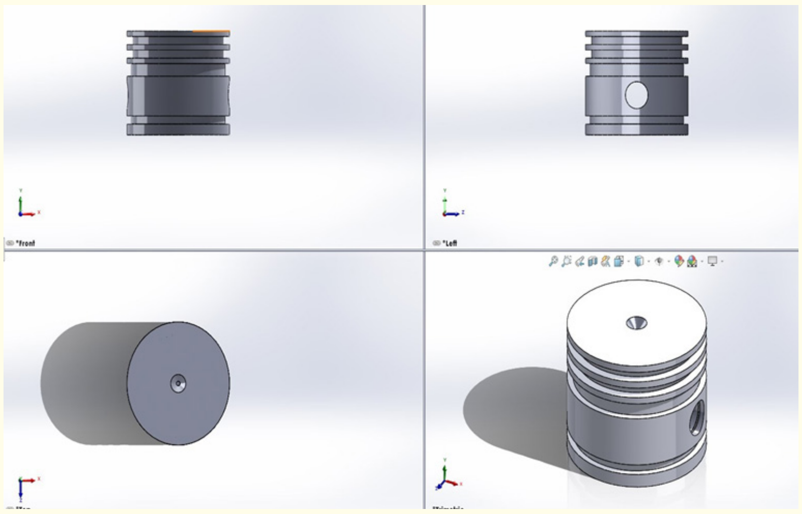

Figure 6: Orthography View.

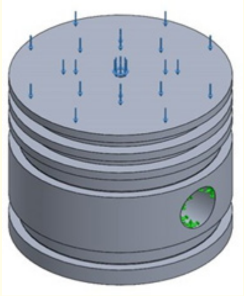

Figure 7: Fix Piston Pin and Applied.

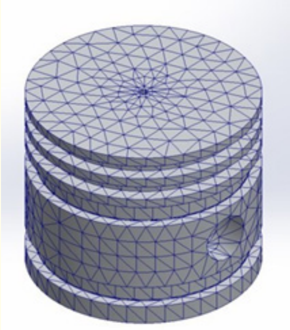

Figure 8: Create Mess.

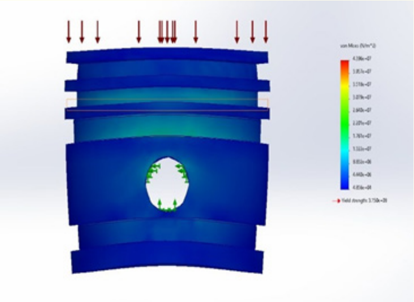

Figure 9: Failure analysis.

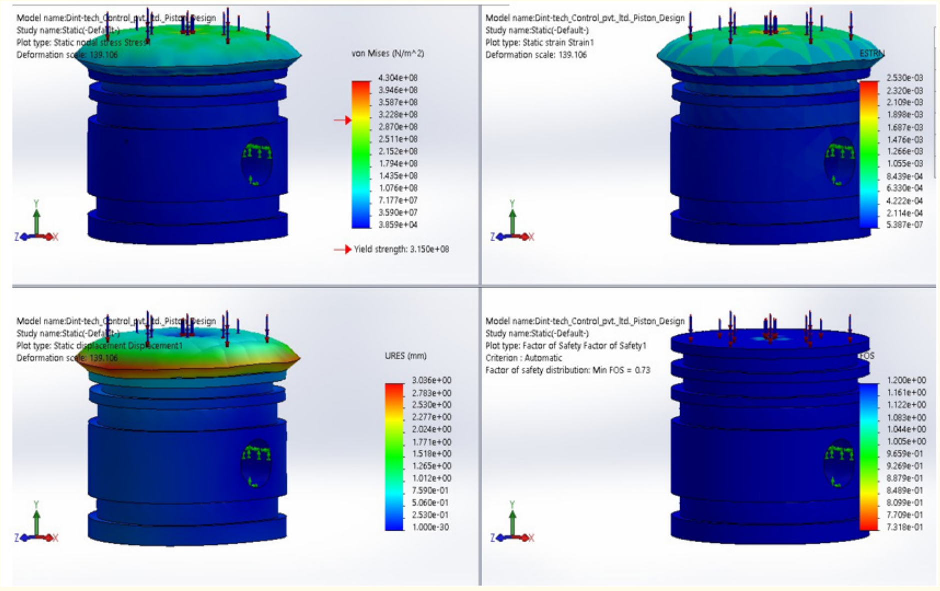

Figure 10: Different types of analysis.

after review many research paper and reference books we able to find two solutions;

- Make a Cup type Piston Head (For Reducing Stress Concentration)
- Increasing Piston Ribs

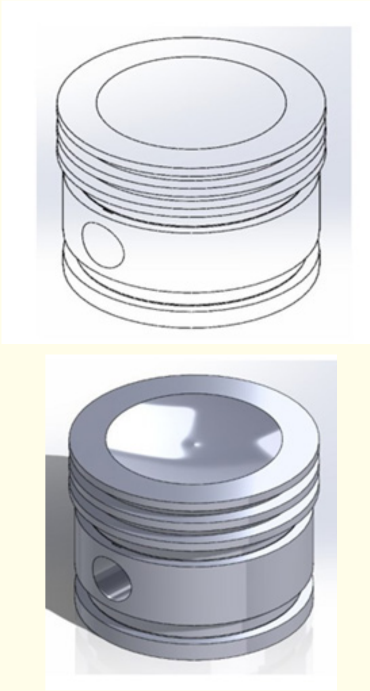

Figure 11: Cup Type Piston.

Make a cup type piston head

For this now we make Re-Design of piston that we are already Design that are show below.

Now for Static analysis of this Piston; we were taking same parameter that we were usebefore but from below result we are say here my experiment is gone fail. Piston is gonebreak they cannot able to absorb 10 bar pressure.

Increasing piston ribs

For this now we make Re-Design of piston that we are already Design and increasingnumber of piston ribs that are show below.

But Again, Piston is Gone fail; show in below Figure.

Result and Discussion

Now it is very challenging task for us to Design Piston but again we are Increasing Piston Ribs then from Static analysis of this Piston and we were taking same parameterthat we were use before and at this time Piston cannot brake (Deformed) and we are able to Design a Piston to absorb 10 bar pressure.

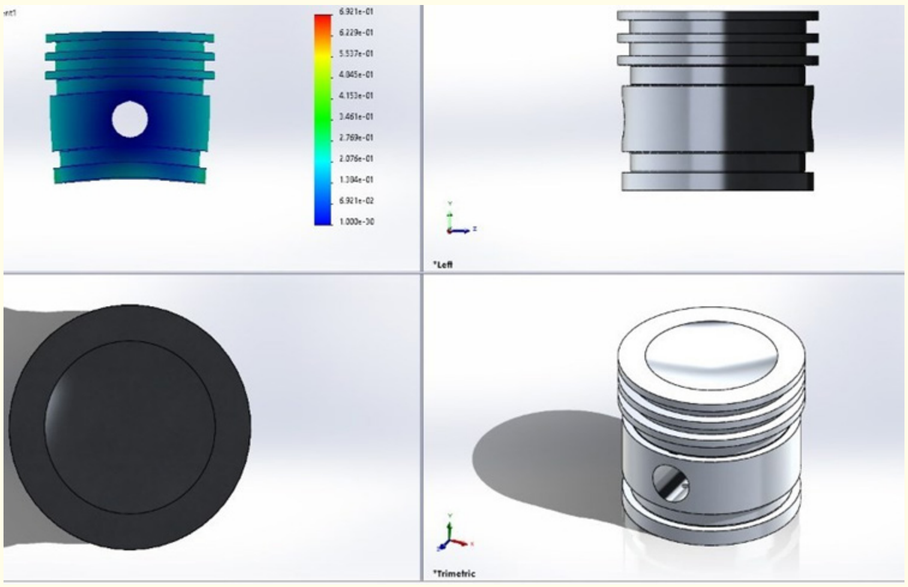

Figure 12

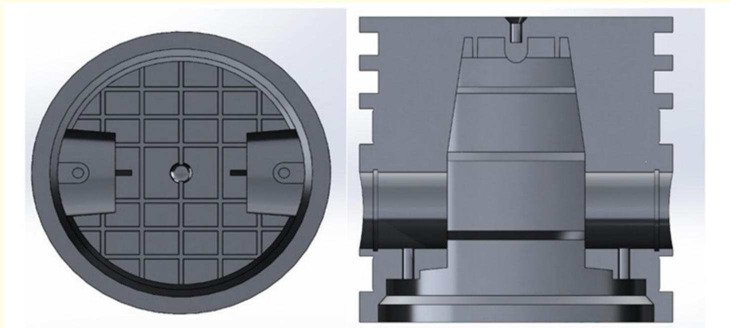

Figure 13: Increasing Piston Ribs.

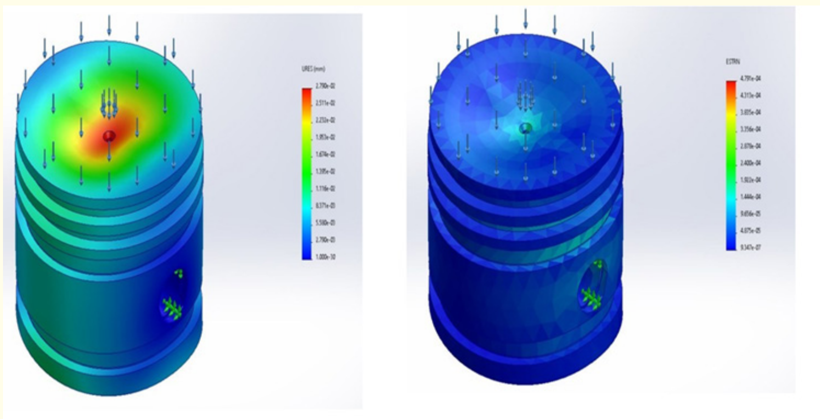

Figure 14

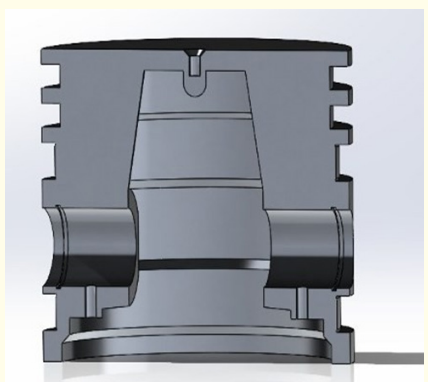

Figure 15: Cross-Sectional Area of Piston.

Comparison Between Different Results.

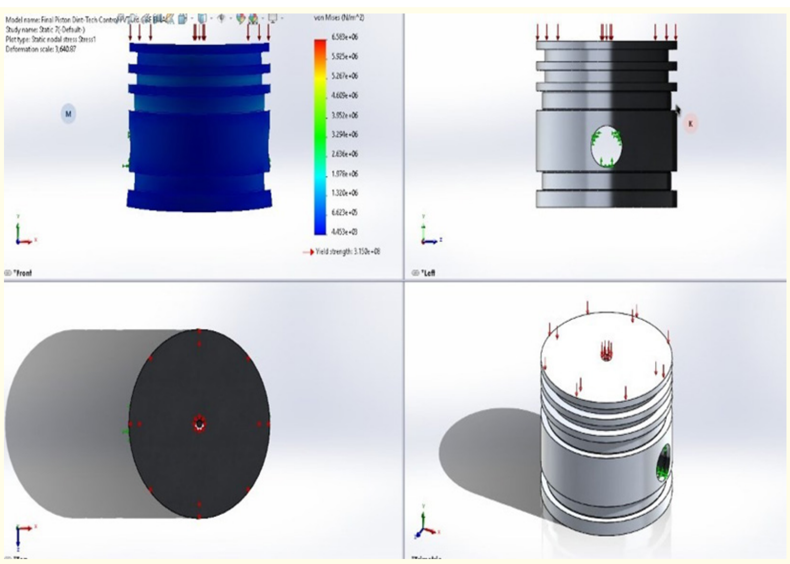

Figure 16: Final Result.

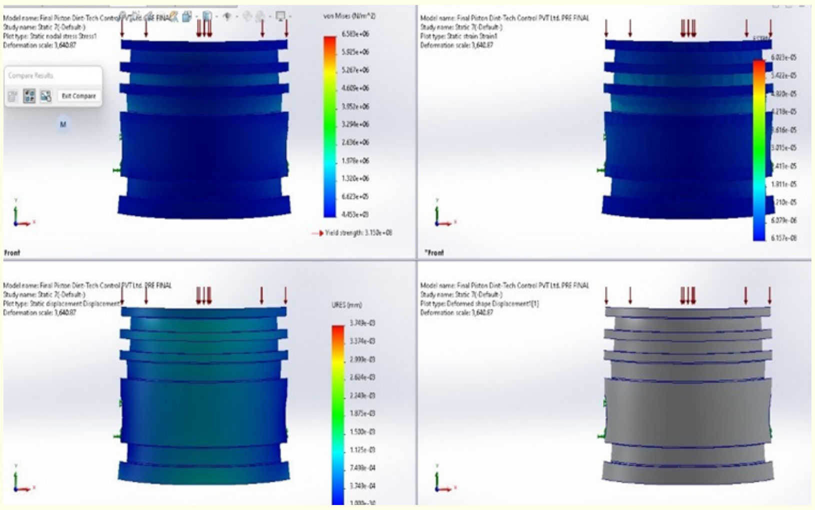

Figure 17: Comparison of Stress, Displacement, Deformation and Strain.

Conclusion

In conclusion, the journey to design a piston capable of withstanding a 10-bar pressure presented significant challenges and valuable lessons. The initial piston design, subjected to both cup-type piston head and increased ribs modifications, proved incapable of meeting the specified pressure requirements.

The iterative nature of the design process became evident as these initial attempts fell short. However, through continuous review, analysis, and numerous redesigns, a breakthrough was achieved. The final piston design, characterized by an increased number of ribs, successfully overcame the pressure absorption issue, as validated by static analysis.

This experience underscores the complexity inherent in piston design and the importance of thorough analysis and perseverance in engineering projects. The journey from initial failure to ultimate success serves as a testament to the resilience and problem-solving capabilities inherent in the engineering process.

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Conflict of Interest

Not Applicable.

Bibliography

1. Manjunatha TR., *et al*. "Design and Static Structural Analysis of Cylinder and Piston of Two Stage Reciprocating Compressors Using ANSYS". *International Journal of Innovative Research in Science, Engineering and Technology* 2.12 (2013).
2. "Experimental Investigation of overall efficiency of two stage reciprocating air compressor by way of intercooling". *International Journal of Advanced Research in Science, Engineering and Technology* 1.3 (2013): 9-14.
3. V Bhandari. Machine Design, Tata-McGraw Hill Publishers.
4. Cavileer A. "Piston Design Improvement Through Research Investigation". SAE Technical Paper 630071, (1963).
5. Prakash Chandra Mishra. "A Review of Piston Compression Ring Tribology". *Tribology in Industry* 36.3 (2014): 269-280.
6. Wikipedia, the free encyclopaedia. History of the Piston (2013).
7. WAI PHYO AUNG and HTAY HTAY WIN. "Design and Analysis of Piston for Two Stages Reciprocating Air Compressor". *International Journal of Scientific Engineering and Technology Research* 3.15 (2014): 3252-3258.

8. https://www.google.com/imgres?imgurl=https%3A%2F%2Fenginefixuk.com%2Fwpcontent%2Fuploads%2F2016%2F06%2FPistons1.jpg&tbnid=82AOkGJ1buDwZM&vet=12ahUKEwi4gsDlku6CAxUT2zgGHQB6C2QQMyhhegUIARDeAg..i&imgrefurl=https%3A%2F%2Fenginefixuk.com%2Fengineproducts%2Fpistons%2F&docid=CL90W3FGlMyYbM&w=640&h=430&q=piston%20photos&ved=2ahUKEwi4gsDlku6CAxUT2zgGHQB6C2QQMyhhegUIARDeAg