P Srinivasulu * et al.
(IJITR) INTERNATIONAL JOURNAL OF INNOVATIVE TECHNOLOGY AND RESEARCH
Volume No.5, Issue No.6, October - November 2017, 7584-7587.

Design Optimization and Analytical Investigations of Hallow Exhaust Valves in I.C Engines

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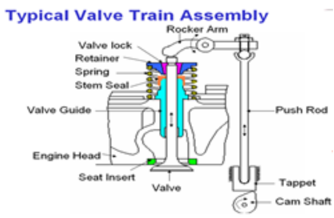
Abstract: **An engine valve is a mechanical device that regulates the supply of fuel to an engine. It is an important part of any engine system and comprised of a stem and a head. Exhaust valve is precision engine components used to open to permit the burned gases to exhaust from cylinders . The heads of the valves are subjected to the high temperature of the burning gases. The Exhaust valves may reach a temperature of 800o cherry red. It is essential that they should not warp under the influence of the heat, and that their seats should not scale or corrode, as in either case they would become leaky. Therefore exhaust valve are exposed to serve thermal loads and chemical corrosion. Exhaust valve opens and closes as many as 2000 times per mile.**

In this thesis, various designs of hollow exhaust valves are modeled using CREO. The modeled hollow valve designs are 1) Straight hollow portion from top of the stem to the bottom of it. 2) Two hollow portions which are collinear to each other. 3) Two parallel hollow portion with a beam at the center. The hollow portion of the designs are filled with sodium. Each of the modeled design is analyzed by CFD software Fluent. It was found that the design 3 had better heat dissipation than other designs. The volume of sodium content affected the heat dissipation property and material surface affected the strength of the exhaust valve. The alternate simple fabrication method is proposed to reduce the complexity of the fabrication method

Keywords: CFD; Hollow valve

I. INTRODUCTION

An engine valve is a mechanical device that regulates the supply of fuel to an engine. It is an important part of any engine system and comprised of a stem and a head. Exhaust valve is precision engine components used to open to permit the burned gases to exhaust from cylinders. The heads of the valves are subjected to the high temperature of the burning gases. The Exhaust valves may reach a temperature of 800o cherry red. It is essential that they should not warp under the influence of the heat, and that their seats should not scale or corrode, as in either case they would become leaky. Therefore exhaust valve are exposed to serve thermal loads and chemical corrosion. Exhaust valve opens and closes as many as 2000 times per mile. On account of high temperature operating conditions, the material for exhaust valve should have 1. High strength and hardness to resist tensile loads and stem wear, 2. High hot strength and hardness to combat head cupping and wear of seats, 3. High fatigue and creep resistance, 4. Adequate corrosion resistance, 5. Least coefficient of thermal expansion to avoid excessive thermal stresses in the head, 6. High thermal conductivity for better heat dissipation. Process involved for the exhaust valve basically need high dimensional accuracy and heat treatment to ensure complete sealing of the combustion chamber. Since the exhaust valve temperatures in modern engines reach very high values of the order of 800°C, cooling of exhaust valves becomes very important. To do this cooling water jackets are arranged as near the valve as possible.



II. LITERATURE REVIEW

Increasing computational power of modern computers, multi-dimensional Computational Fluid Dynamics (CFD) has found more and more applications in diesel engine research, design and development. Various successful applications have proven the reliability of using multidimensional CFD tools to assist in diesel engine research, design and development. By using CFD tools effectively it is easy to predict and analyse various details that are technically difficult like in cylinder process of diesel combustion, temperature & pressure contours, emission etc. prior to experimental tests to reduce the number of investigated parameters as well as time and thus costs. A multidimensional model was created and analysis of combustion was done using FLUENT, ANSYS 14.5 package.

INTRODUCTION TO CAD

Computers are being used increasingly for both design and detailing of engineering components in the drawing office. Computer-aided design (CAD) is defined as the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system.

INTRODUCTION TO PRO/ENGINEER

Pro/ENGINEER, PTC's parametric, integrated 3D CAD/CAM/CAE solution, is used by discrete manufacturers for mechanical engineering, design and manufacturing. This powerful and rich design approach is used by companies whose product strategy is family-based or platform-driven, where a prescriptive design strategy is critical to the success of the design process by embedding engineering constraints and relationships to quickly optimize the design, or where the resulting geometry may be complex or based upon equations. Pro/ENGINEER provides a complete set of design, analysis and manufacturing capabilities on one, integral, scalable platform.

INTRODUCTION TO FEA

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

INTRODUCTION TO ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations. ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

INTRODUCTION TO CFD

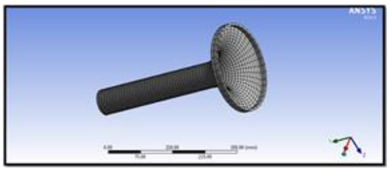
Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

III. RESULTS & DISCUSSIONS

CFD ANALYSIS OF HOLLOW EXHAUST VALVE

Geometry Model

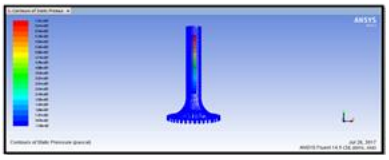
Meshed Model



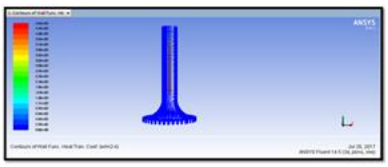
HOLLOW EXHAUST VALVE WITH STEM

AT VELOCITY-10m/s

PRESSURE



HEAT TRANSFER COEFFICIENT



MASS FLOW RATE

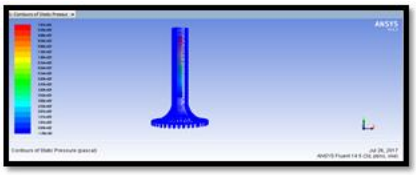
```
        Mass Flow Rate                    (kg/s)
 -------------------------------- --------------------
                    inlet              1.4898069
     interior-_____msbr             -120.64045
                   outlet             -1.4980688
         wall-_____msbr                        0
 -------------------------------- --------------------
                      Net           -0.00026190281
```

HEAT TRANSFER RATE

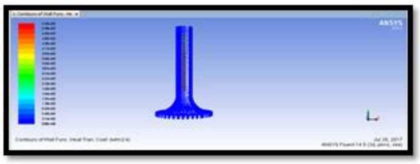
```
 Total Heat Transfer Rate                      (w)
 -------------------------------- --------------------
                    inlet                  3509306
                   outlet               -3509922.8
         wall-_____msbr                          0
 -------------------------------- --------------------
                      Net                  -616.75
```

AT VELOCITY-12m/s

PRESSURE



HEAT TRANSFER COEFFICIENT



MASS FLOW RATE

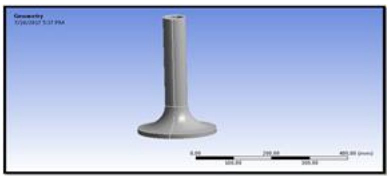
```
        Mass Flow Rate                    (kg/s)
 -------------------------------- --------------------
                    inlet              1.7877681
     interior-_____msbr             -144.77077
                   outlet             -1.788007
         wall-_____msbr                        0
 -------------------------------- --------------------
                      Net           -0.00023889542
```

HEAT TRANSFER RATE

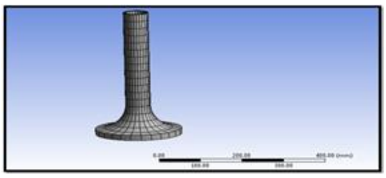
```
 Total Heat Transfer Rate                      (w)
 -------------------------------- --------------------
                    inlet                4211166.5
                   outlet               -4211729.5
         wall-_____msbr                          0
 -------------------------------- --------------------
                      Net                     -563
```

THERMAL ANALYSIS OF HOLLOW EXHAUST VALVE

IMPORTED MODEL



MESHED MODEL



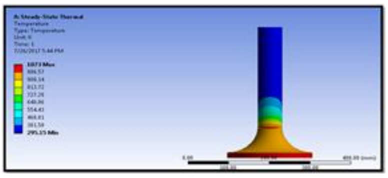
BOUNDARY CONDITIONS

MATERIAL -ALUMINUM ALLOY

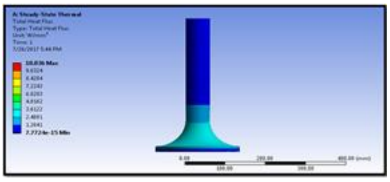
HOLLOW EXHAUST VALVE WITH STEM

AT VELOCITY-10m/s

TEMPERATURE

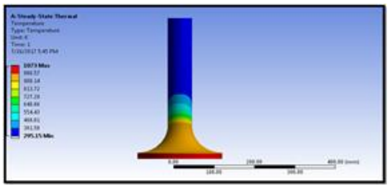


HEAT FLUX

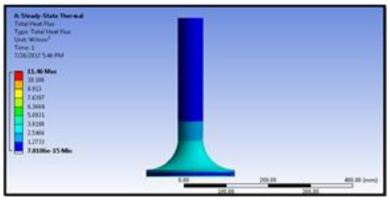


AT VELOCITY-12m/s

TEMPERATURE



HEAT FLUX



RESULT TABLES

CFD RESULTS

CASES	INLET VELOCITY (m/s)	PRESSURE (Pa)	Heat transfer coefficient(W/m²k)	Mass flow rate(kg/sec)	Heat transfer rate(w)
HOLLOW	10	7.26e+02	3.96e+03	0.0560321181	131988
	12	1.03e+03	4.64e+03	0.064642	152270
WITH STEAM	10	7.27e+03	4.66e+04	0.0002	616.75
	12	1.01e+04	5.48e+03	0.00238	563
WITH BEAM	10	5.47e+04	3.60e+03	0.010732	25281
	12	7.98e+04	4.03e+03	0.0013766	3239.5

THERMAL RESULTS

MATERIAL -STAINLESS STEEL

Cases	Inlet velocity	Temperature		Heat flux(w/mm²)
		Min	Max	
Hollow	10	294.06	1073	1.6465
	12	294.02	1073	1.7157
With steam	10	273.15	1073	1.9847
	12	273.15	1073	2.0601
With beam	10	255.6	1073	2.5624
	12	252.12	1073	2.6254

MATERIAL -ALUMINUM ALLOY

Cases	Inlet velocity	Temperature		Heat flux(w/mm^2)
		Min	Max	
Hollow	10	295.15	1073	6.9237
	12	295.15	1073	7.7805
With steam	10	295.15	1073	10.836
	12	295.15	1073	11.46
With beam	10	295.15	1073	11.861
	12	295.15	1073	12.488

IV. CONCLUSION

Hence three novel designs of the exhaust valve is designed using CREO. Thermal and CFD analysis of the designs are performed by ANSYS. In this thesis, various designs of hollow exhaust valves are modeled using CREO. The modeled hollow valve designs are 1) Straight hollow portion from top of the stem to the bottom of it. 2) Two hollow portions which are collinear to each other. 3) Two parallel hollow portion with a beam at the center.

By observing the CFD analysis the heat transfer coefficient values is more at exhaust valve with stem compare with hollow and with beam type valves.

By observing the thermal analysis the heat flux value is more for titanium alloy.

So it can be concluded the with beam exhaust valve by the material is aluminium alloy is the better performed.

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