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Static and Thermal Analysis of Internal Combustion Engine Valves

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Abstract: In this paper the 3D model of the internal combustion engine valves was realized using Autodesk Inventor Professional 2024 and finite element analysis, static and thermal was performed, in order to determine the state of stress, deformation and temperature evolution, by applying restrictions and loads conditions. Two materials were chosen, for internal combustion engine valves, in accordance with the specialized literature. The materials taken for static and thermal analysis was Stainless Steel AISI 446 and NiCr0TiAl. Following the comparative study for the two models, it can be specified the importance of the material for the construction of the internal combustion engine valves who depends on the material properties and their design.
Keywords: Combustion engine valves, Solid modeling, Static and thermal analysis, Autodesk Inventor

I. INTRODUCTION

Ragul G., Samrat Majumdar et al. [1] in their paper studied the stresses induced in a combustion engine valve due to high thermal gradient and high pressure inside the combustion chamber. To analyze the FEM of the combustion engine valve they used the dedicated ANSYS software, and make a thermal and structural analysis on the combustion engine valve. In the first stage of the analysis, they determined the temperature distribution on the combustion engine valve, and in the second stage the temperature distribution was transferred to another element and the pressure stress was applied to the combustion engine valve to determine the displacement distribution. In the analysis they looked at different materials in order to choose the best material for the combustion engine valve based on its strength and thermal properties.

Pandey A. and Mandloi R. K. [2] studied combustion engine valve damage by analyzing the changes of temperature that lead to a change in the size of the crystalline grains of the material, with an influence on greater wear of the combustion engine valve. Mamilla V. R. [3] studied intake and exhaust valve damage under different operating conditions such as fatigue, high pressure inside of cylinder and due to impact loading.

Ashouri H. [4] introduced the concept of reduction of thermomechanical damage by cyclic testing under low compressive stress and also reduction of fatigue crack and life, of combustion engine valves by FEM analysis method. Baek H. [5] studied the increase in engine fuel consumption, impact behavior and also combustion engine valve durability. Raghuwanshi N. Kr. et.al. [6] studied damage to intake and exhaust valves due to thermal effect.

The combustion engine valve consists of 2 areas. One area represented by the plate and the second area by the valve stem. The combustion engine valve plate has the purpose of closing the opening of the intake or exhaust channel, channel located in the cylinder head. The rod has the role of transmitting the movement transmitted by the rocker-arm to the valve. In addition to the role of receiving the movement transmitted by the rocker-arm, the valve stem has the role of guiding the combustion engine valve and receiving a portion of the heat coming from the valve plate.

The combustion engine valve is generally loaded by the pressure force of the gases and the elastic force of the valve spring, these forces acting mainly on the valve plate. During operation of the timing mechanism, the valve disc is additionally stressed by shock, stress produced by the forces of inertia and the elastic force of the spring, when the valve returns to its seat [7]. The valve stem is also stressed by shock when the rocker arm acts on it. Because of this, the end of the valve stem and the conical area of the valve plate must have an increased surface hardness [7]. The combustion engine valve is also thermally stressed, especially the exhaust one, due to the fact that it is washed by the burnt gases, gases that reach temperatures around 900 °C. The most thermally stressed area of the exhaust valve reaches up to 825 °C.

Due to the fact that during the operation of the internal combustion engine the temperature of the exhaust valve can reach values in the range of 450÷825 °C, the mechanical resistance and the hardness of the material are considerably reduced, it is necessary that the choice of the material from which the exhaust valve is made with special attention.

The material from the combustion engine valve must be the following requirements: have high mechanical resistance at high temperatures; to resist the corrosive action of exhaust gases; to have a high thermal conductivity and to have a coefficient of friction as low possible. The intake valve is made of chrome-nickel or chrome-silicon alloy steel, using steel grades such as: 40C-10X, 35CN15X, and is made from one piece [7].

II. COMBUSTION ENGINE VALVE DESIGN

Solid modelling of the combustion engine valve was done using Autodesk Inventor, version 2024 with the literature data, the solid model of the combustion engine valve is shown in Fig. 1.

Fig. 1 Combustion engine valve design

III. STATIC ANALYSIS

A. *Choosing Material*

The paper compares the values obtained for two materials used in the construction of the combustion engine valve: Stainless Steel AISI 446 and NiCr20TiAl. Materials and their properties are shown in Table 1.

TABLE I

MATERIAL PROPERTIES

Parameters	*Stainless Steel AISI 446*	*NiCr20TiAl*
Young's Modulus [MPa]	113763	190000
Poisson's Ratio	0.35	0.29
Shear Modulus [MPa]	42057	74000
Mass Density [Ns^2/mm^4]	8E-09	8.3E-09
Tensile Strength [MPa]	1034.210	1150
Yield Strength [MPa]	882.525	670
Thermal Expansion Coefficient	9.54E-06	1E-07
Thermal Conductivity N/(sec ^oC)	1.620E+01	1E-01
Specific Heat $mm^2/(sec^2\ ^oC)$	5E+08	1E+08

B. *The Restrictions and Load Condition*

Restrictions have been imposed according to the indications in the specialized literature [6, 7] and a force of 500 N is applied to the combustion engine valve shaft, due to the gas pressure force [7], as show in Fig. 2.

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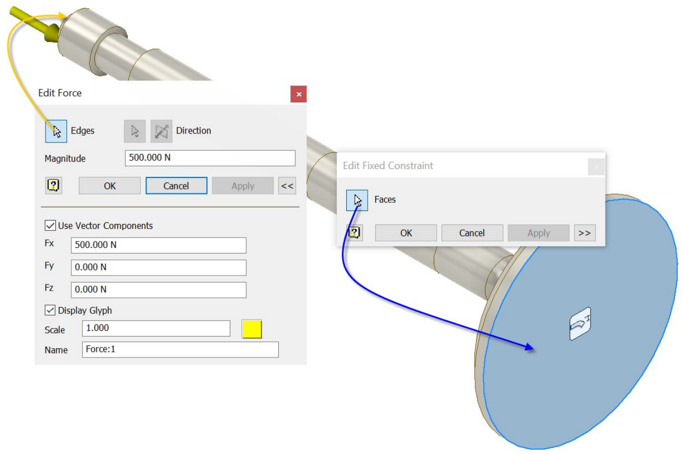

Fig. 2 Restrictions and load condition

C. Generate Meshing

To generate the mesh, the automatic generation mode was used with parabolic element order, the model being meshed into 4619 elements and 7928 nodes, Fig. 3.

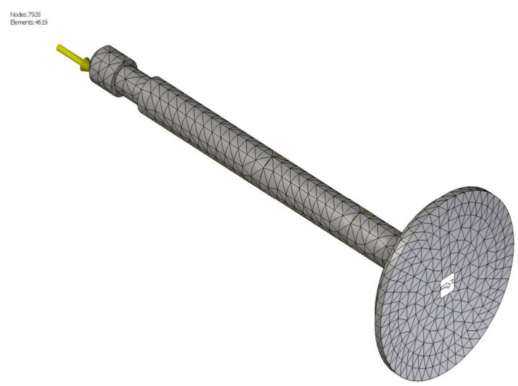

Fig. 3 Combustion engine valve meshing

D. Static Analysis Results

Next, the simulation was run and the results of the static analysis were obtained, presented in the following figures. Figure 4 shows the Von Mises Stresses values obtained in the case of Stainless Steel AISI 446 combustion engine valve, it can be seen that their maximum value was 118.2 MPa and Figure 5 shows the Von Mises Stresses values obtained in the case of NiCr20TiAl combustion engine valve, maximum value was 124.5 MPa, both below the material's yield point.

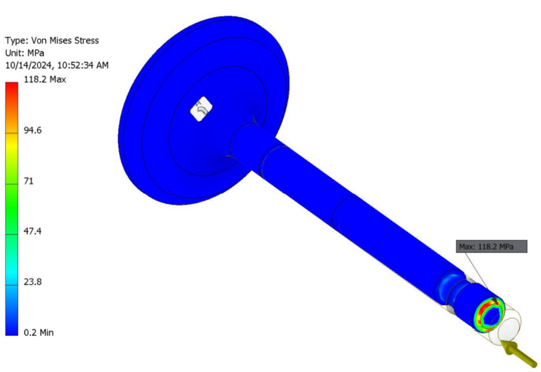

Fig. 4 Von Mises Stress – *Stainless Steel AISI 446*

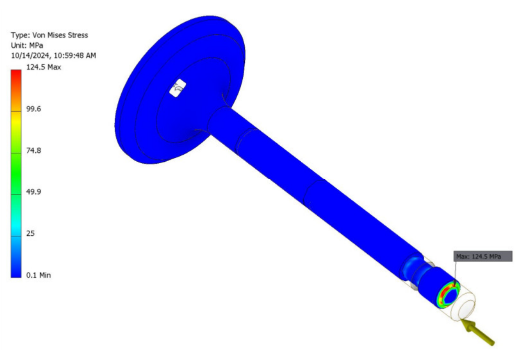

Fig. 5 Von Mises Stress – *NiCr20TiAl*

Figure 6, 7 shows the results regarding of the maximum deformations of the combustion engine valve. A maximum deformation, 0.0131 mm, was recorded for Stainless Steel AISI 446 combustion engine valve and a maximum deformation 0.078 mm in the case of NiCr20TiAl combustion engine valve.

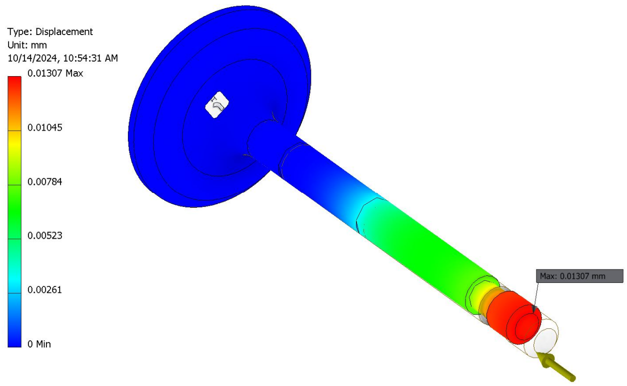

Fig. 6 Deformation – *Stainless Steel AISI 446*

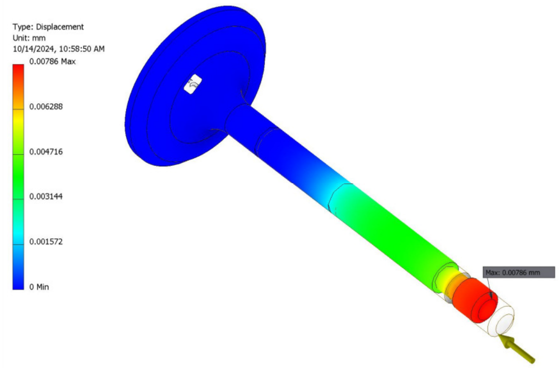

Fig. 7 Deformation – *NiCr20TiAl*

The minimum value of the safety factor was 7.47, for Stainless Steel AISI 446 combustion engine valve, Fig. 8 and 5.38 for NiCr20TiAl combustion engine valve, Fig. 9.

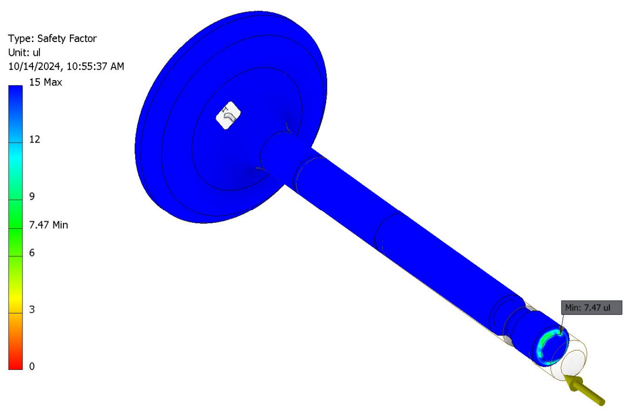

Fig. 8 Safety factor – *Stainless Steel AISI 446*

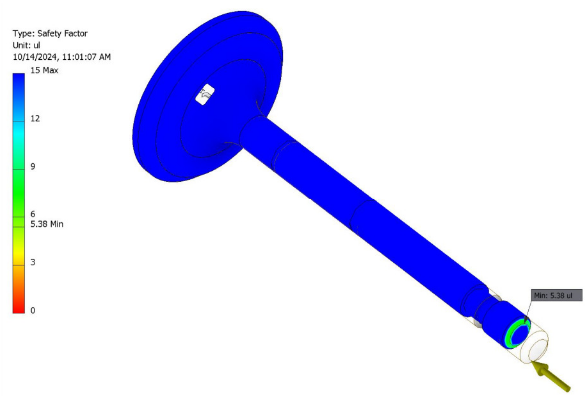

Fig. 9 Safety factor – *NiCr20TiAl*

IV. THERMAL ANALYSIS

A. Choosing Material

The thermal analysis of the combustion engine valve was also performed with Autodesk Inventor 2024, but this time the special module dedicated to FEM analysis, Nastran, was used. The same materials were chosen as in the case of the static analysis.

B. Generate Meshing

To generate the mesh, a fine discretization of the model was chosen in order to obtain the most accurate results and to avoid possible errors arising due to a coarse discretization, Fig. 10.

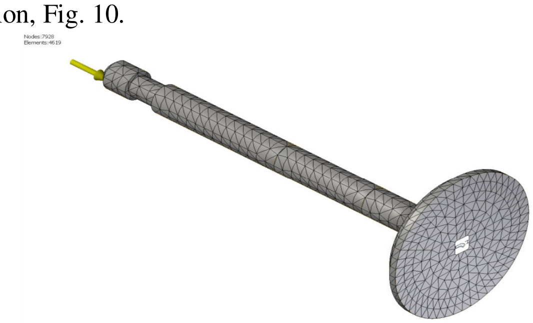

Fig. 10 Combustion engine valve meshing

C. The Load Condition

A series of conditions were imposed, including: the action of the gases in the cylinder was defined by thermal convection, Table II and the heat flow taken by the combustion engine valve was also applied, according to the literature of 60 mW/mm^2, Fig. 11…12.

TABLE III

LOAD CONVECTION

Valve Section	*Convection Coefficient [mW/mm^2K]*	*Ambient Temperature [K]*
Combustion face	0.413	1040.48
Valve seat	1.309	678.07
Valve stem to port	0.139	1031.37
Stem guide to port]	0.276	638.20
Valve stem to guide	0.281	370
Valve stem to guide to tip	0.495	374.89
Stem to tip	0.5	375

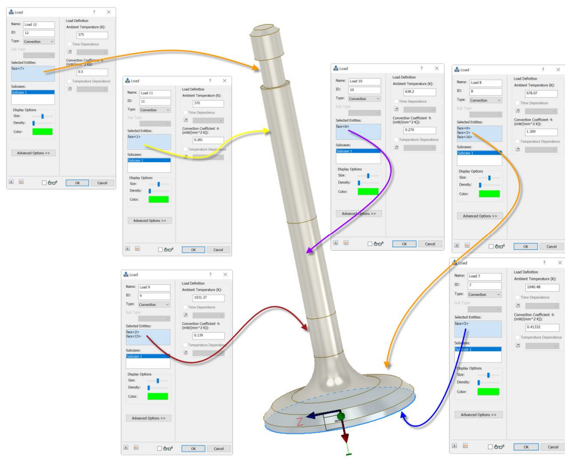

Fig. 11 Restrictions and thermal convection

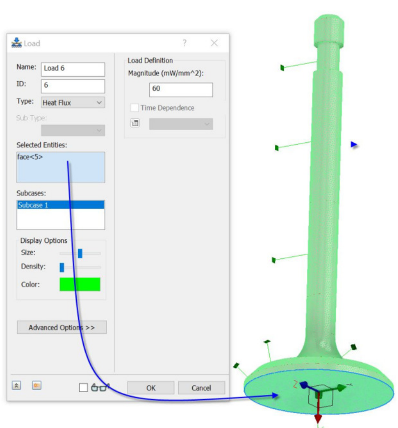

Fig. 12 Valve heat flow

D. Thermal Analysis Results

The results obtained from the thermal analysis are in accordance with those in the specialized literature and it is observed that the temperature increases from the end of the rod towards the plate, due to the fact that the combustion engine valve plate has a smaller diameter and the surface that comes in contact with the hot gases from the combustion chamber is small.

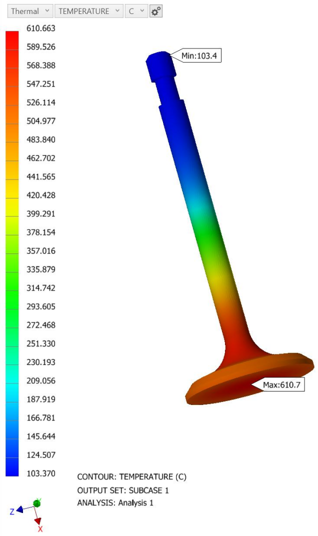

Fig. 13 Temperature – Stainless Steel AISI 446

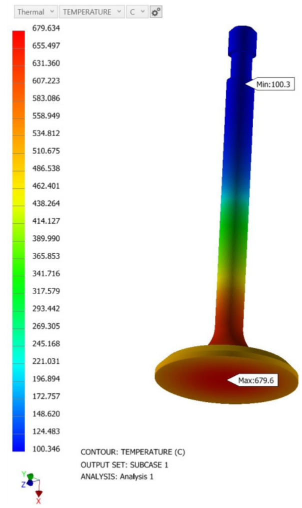

Fig. 14 Temperature – NiCr20TiAl

The values being relatively low, approximately 610.7^{o}C, in case of Stainless Steel AISI 446 valve, Fig. 13, compared to the maximum values for NiCr20TiAl valve who was 679.6^{o}C, Fig. 14.

V. CONCLUSION

The static and thermal analysis of internal combustion engine valves made from Stainless Steel AISI 446 and NiCr20TiAl reveals significant insights into their performance and suitability for high-stress environments.

Static analysis shows that engine valves made from NiCr20TiAl typically offers a higher strength-to-weight ratio compared to engine valves made from Stainless Steel AISI 446, which can lead to improved response times and reduced inertial forces. However, engine valves made from Stainless Steel AISI 446 often provides better fatigue resistance under cyclic loading conditions, making it a reliable choice for certain applications.

Thermal analysis indicates that engine valves made from NiCr20TiAl generally have superior thermal stability and lower thermal conductivity, which can be advantageous in managing heat in high-temperature environments. In contrast, Stainless Steel AISI 446 engine valves may exhibit better overall thermal conductivity, allowing for more efficient heat dissipation.

Ultimately, the choice between Stainless Steel AISI 446 and NiCr20TiAl for engine valves depends on specific application requirements, including weight, thermal management, and durability. A balanced approach considering both static and thermal properties will ensure the optimal performance and longevity of engine valves in demanding conditions.

REFERENCES

[1] G. Ragul, S. Majumdar, S. Sankar, P. Prakash, J. Dehesinghraja, "Thermo Mechanical Analysis of Engine Valve and Valve Seat Insert by Finite Element Method", International Journal of Pure and Applied Mathematics ISSN 1314-3395, Vol. 119 No. 16 pp 821-832, July 2018.

[2] A. Pandey, R. K. Mandloi, "Effects of High Temperature on the Microstructure of Automotive Engine Valves", Int. Journal of Engineering Research and Applications, Vol. 4, Issue 3 (Version 1), pp.122-126, March 2014.

[3] V. R. Mamilla, "Failure Analysis of Internal Combustion Engine Valves by using Ansys", American International Journal of Research in Science, Technology, Engineering & Mathematics, 5(2), pp. 169-173, December 2013-February 2014.

[4] H. Ashouri, "Thermo-Mechanical Analysis of Diesel Engines Cylinder Heads using a Twolayer Viscoelasticity Model with Considering Viscosity Effects" International Journal of Automotive Engineering, Volume 5, number 2; page(s) 1026 to 1038, June 2015.

[5] H. Baek, "Development of Valve train System to Improve Knock Characteristics for Gasoline Engine Fuel Economy Development of Valve train System to Improve Knock Characteristics for Gasoline Engine Fuel Economy", SAE Technical Paper 2, 2014.

[6] N. Kr. Raghuwanshi, A. Pandey, R. K. Mandloi, "Failure Analysis of Internal Combustion Engine Valves: A Review", International Journal of Innovative Research in Science, Engineering and Technology Vol. 1, Issue 2, December 2012.

[7] B. Grunwald, Teoria, Calculul şi Construcţia Motoarelor pentru Autovehicule Rutiere. Bucureşti: Editura Didactică şi Pedagogică, 1980.