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Finite Element Simulation for Improved Design of Plastic Intake Manifold for Four Cylinder Engines

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ABSTRACT:
In order to reduce the weight for improving fuel efficiency and enhance the performance of automobile engines, research into plastic manifolds compared to conventional aluminium and iron manifolds is becoming a trend for the intake structure design. In this paper, finite element simulation is employed to design and optimize a plastic manifold for a four cylinder intake structure. The yield strength of intake manifold structure for an applied burst pressure of 6.5bar is verified using finite element analysis. Based on the simulation results and identification of strength critical zones, stiffeners were introduced to improve the plastic intake manifold design for an operational temperature range of 20-120 degrees Celsius.

KEYWORDS:
Plastic intake manifold; Structure design; Yield strength; Optimization

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1. Introduction

Intake manifold is one of the important parts of an automobile engine. Its structure and performance directly affect economy, power performance and emission index of automobile. At present plastic intake manifold is widely used in the automobile industry in developed countries because of low weight and simple processing at low cost. Application of plastic intake manifold in developing countries is relatively small due to the limitations of technology. Hao et al. [3] analyzed the dynamic response of original and improved models of the bulk cement semi-trailer tank and frame using finite element (FE) analysis software ANSYS, including modal analysis and harmonic response analysis and put forward some proposals to optimize the structure and provided reliable theoretical basis.

Gang [4] analyzed the work principle of variable intake manifold technology for vehicle engine structure and their characteristics. Zhipei [10] studied the trend of domestic and foreign automotive plastics. Hua and Cheng [6] presented excellent characteristics and usage of plastics in the interior, exterior and parts under hood and the trend in automobile plastics. Siqin and Xuehong [1] obtained the distribution of airway pressure velocity and other parameters based on 3D modeling, which laid a solid basis for further optimization of design [2]. Jian et al. [8] carried out steady state experiments using the pressure difference method, which broke the previous constant pressure difference method and got good results. Steady flow test enabled researchers ([11] and [12]) to better understand the influence of the shape of intake manifold structure on the flow state.

In this paper, the structure of a four cylinder plastic intake manifold was designed using PRO/E software. The yield strength of manifold at 6.5bar burst pressure was analyzed using MSC/PATRAN software to obtain a finalised design. In this paper, virtual prototype [5] was used to find a workable solution before the production as an alternative to physical prototype, which might perfectly forecast the product reliability in its entire life cycle and reduce product design & development cost.

2. FE Modelling

Engine intake manifold consists of main pipe, branch pipe and chamber structure as schematically shown in Fig. 1. The intake main and branch pipe diameters are 44mm and 30mm respectively. Wall thickness is 3mm. Intake chamber volume is 1 litre. The design has to withstand a burst pressure of 6.5bar for an environment temperature range of -30°C to 130°C. The largest mass should be not more than 1.2±0.2 kg (excluding the sensor mass). A 3D CAD model of the manifold is shown in Fig. 2. The mechanical properties of Nylon PA6+GF30 manifold material are given in Table 1.

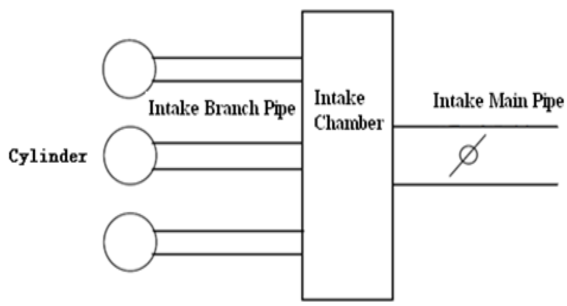

Fig. 1: Schematic of intake manifold structure

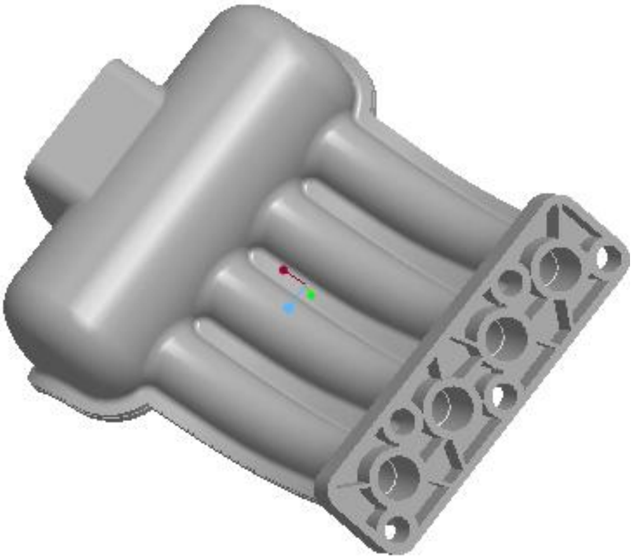

Fig. 2: CAD model of automobile intake manifold structure

Table 1: Nylon PA6+30%GF material properties [9]

Parameters at Temperature	23 ºC	120 ºC
Elastic modulus (MPa)	5155	2400
Yield strength (MPa)	90	38
Density (kg/m^3)	1350	
Coeff. thermal expansion (m/ºC)	5.75x10^{-5}	

FE simulation of plastic intake manifold was carried out using NASTRAN 2005 software. The CAD model was exported from PRO/E 5.0 software to an x-t format for meshing in PATRAN 2008. The CAD model is meshed using tetrahedral (TET10 type) elements. The meshed model has 155452 elements and 279878 nodes. FE model of intake manifold is shown in Fig. 3. Five bolt holes were fixed in all degrees of freedom (see circled mark in Fig. 3). The 6.5bar blast pressure was applied over the nodes on the inner surface of intake manifold structure.

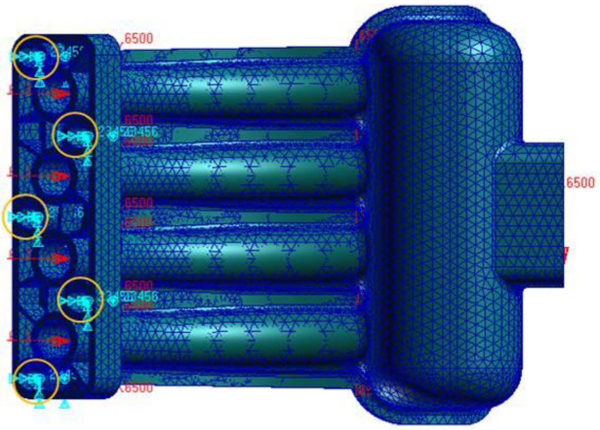

Fig. 3: FE model of intake manifold structure with fixed boundary conditions (circled) and applied blast pressure of 6.5bar over its inner surface

3. Results and Discussions

A linear static analysis of the baseline plastic intake manifold for 23 ºC and 120 ºC was undertaken using NASTRAN 2005 solver. The simulation results are shown in Fig. 4 to Fig. 7. The maximum displacement at 20 ºC and 120 ºC are 0.67mm and 1.44mm respectively. The peak stress of 44.7MPa at 120 ºC is on the surface of the intake chamber. The yield strength of PA6+GF30 material is 38MPa at 120 ºC. Therefore, the plastic intake manifold did not meet the strength requirements for burst pressure.

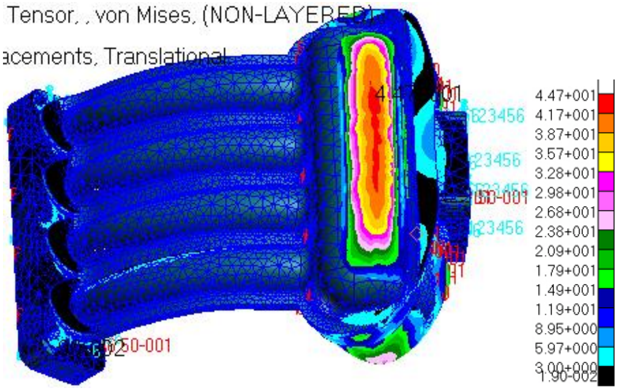

Fig. 4: Von Mises stress plot of baseline intake manifold at 23 ºC

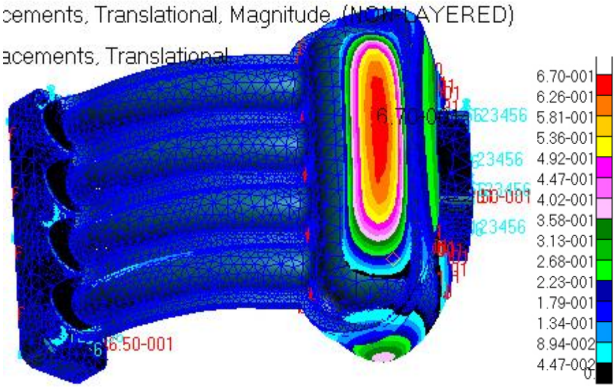

Fig. 5: Displacement plot of baseline intake manifold for 23 ºC

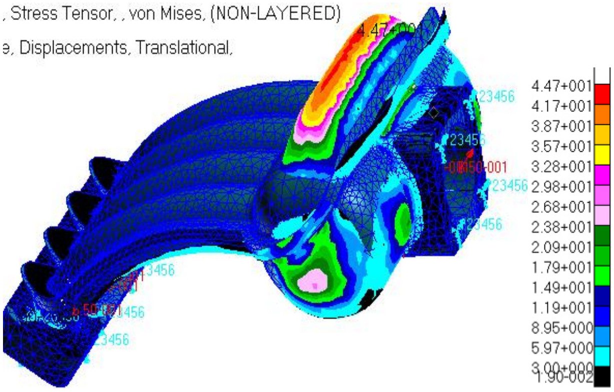

Fig. 6: Von Mises stress plot of baseline intake manifold at 120 ºC

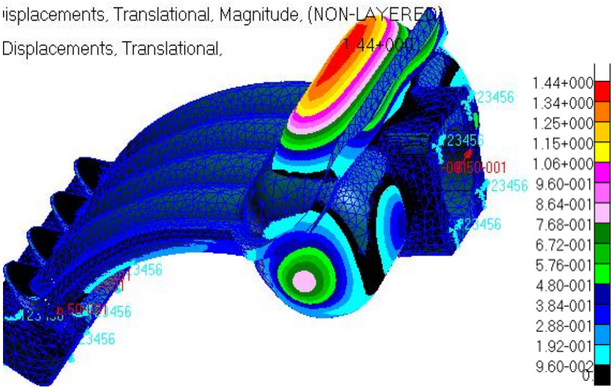

Fig. 7: Displacement plot of baseline intake manifold at 120 ºC

The plastic intake manifold structure design for yield strength can be improved by increasing the wall thickness or introducing stiffeners. Increasing wall thickness increases the material consumption and prolongs the injection cooling time. Therefore, authors adopted the use of stiffeners to optimize the intake manifold structure design. Considering convenience of manufacturing mould and structure symmetry, two stiffeners were introduced on the intake chamber surface as shown in Fig. 8. In order to avoid localised stress concentration around stiffener, stiffener thickness is generally in the range of 50-70% of wall thickness [7]. Two stiffeners of size 1.5mmx1.5mm were introduced over the chamber as shown in Fig. 9.

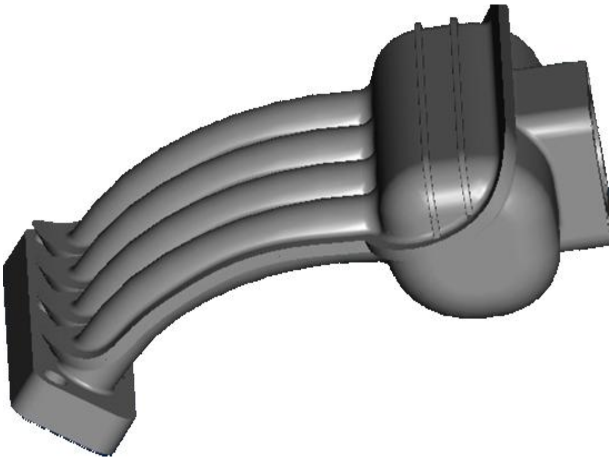

Fig. 8: Location of stiffeners (x2) on the intake manifold chamber

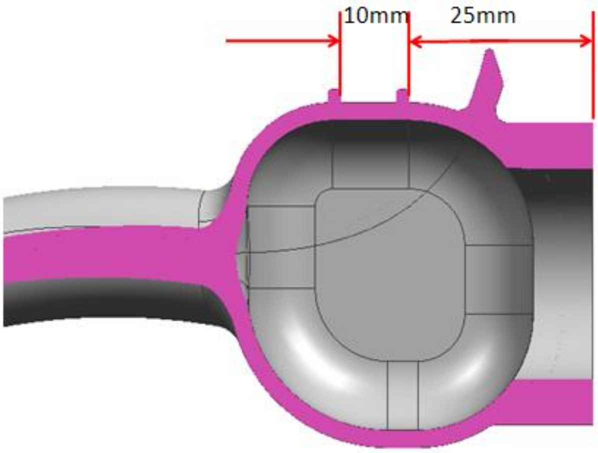

Fig. 9: Cross section view of manifold structure with stiffeners

A linear static analysis of improved plastic intake manifold structure for 23 ºC and 120 ºC was undertaken using NASTRAN 2005 solver. The simulation results are shown in Fig. 10 to Fig. 13. The maximum displacement at 20 ºC and 120 ºC are 0.429mm and 0.921mm respectively. The peak stress at 120°C is 34.9MPa. As the yield strength of PA6+GF30 material is 38MPa at 120°C, which is above the applied stress of 34.9MPa, it can be concluded that the improved intake manifold design with two stiffeners on the chamber has met the design requirements.

In order to verify the rationality of the improved intake manifold design, modal analysis was conducted. First mode shapes at 23 ºC and 120 ºC are shown in Fig. 14 and Fig. 15 respectively. Natural frequencies of the improved intake manifold structure are 378.1Hz and 258Hz for the considered temperatures. These frequencies met the requirement of engine constant speed resonance response.

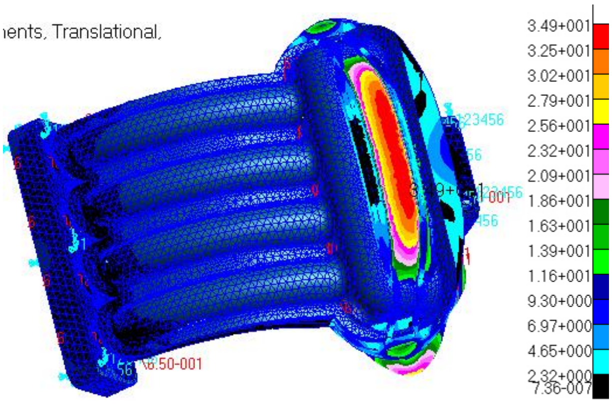

Fig. 10: Von Mises stress plot of improved intake manifold at 23 ºC

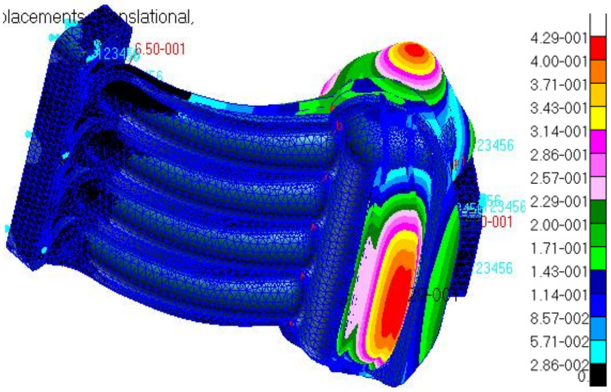

Fig. 11: Displacement plot of improved intake manifold for 23 ºC

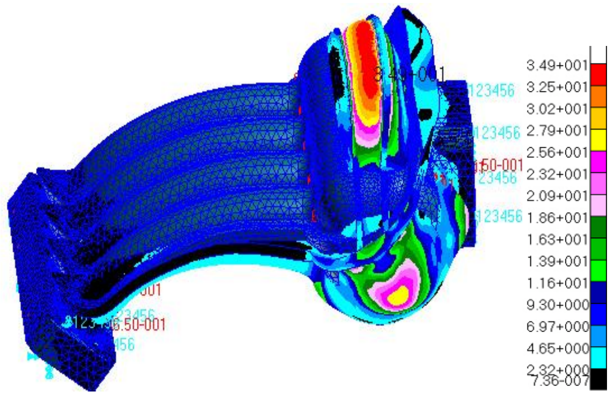

Fig. 12: Von Mises stress plot of improved manifold at 120 ºC

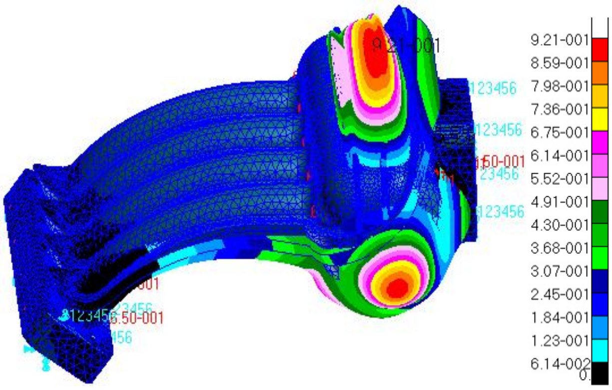

Fig. 13: Displacement plot of improved intake manifold at 120 ºC

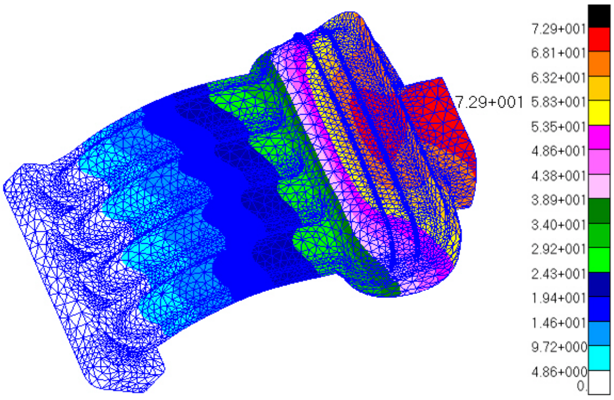

Fig. 14: First mode (378.1Hz) of improved intake manifold at 23 °C

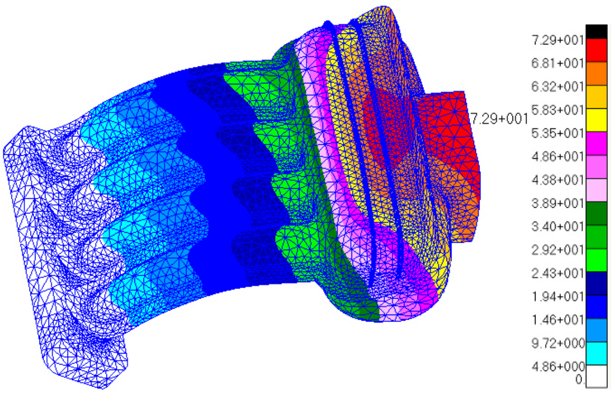

Fig. 15: First mode (258Hz) of improved intake manifold at 120 °C

4. Conclusions

In this paper, authors designed plastic intake manifold structure and carried on the stress analysis when bursting pressure was 6.5bar and environment temperament was 23 °C and 120 °C using MSC/PATRAN and NASTRAN software. FE simulation results were used to improve the design by introducing stiffeners on its chamber to fulfil the yield strength requirements. The finalised design was also verified for the stiffness requirements. The use of FE simulation based virtual prototype technology had benefitted the product development at lesser cost and shorter span of time.

REFERENCES:

[1] C. Siqin and L. Xuehong. 1999. Numerical simulation of gas flow in diesel helical inlet port, *J. Chinese Internal Combustion Engine Engg.*, 4, 43-46.

[2] C. Siqin and L. Xuehong. 2000. Research on 3-D modeling design of helical intake ports, *J. Chinese Internal Combustion Engine Engg*., 3, 23-27.

[3] D. Hao, H. Yunxin, X. Wenshang and Chen Hui. 2010. Research based on CFD for engine intake manifold, *Equipment Manufacturing Tech*, 4, 55-57.

[4] L. Gang. 2009 Study on variable intake manifold technology of engine, *Equipment Manufacturing Tech.*, 1, 24-27.

[5] L. Jianwei and Z. Xueyi. 2011. Optimal design and analysis of the exhaust turbine air-intake manifold on vehicles based on ANSYS, *Agricultural Equipment and Vehicle Engg.*, 1(6), 46-47.

[6] P.Y. Hua and L.Y. Cheng. 2001. The application of new plastics in automobile, *Engg. Plastics Applications*, 29(6), 27-29.

[7] W. Hong. 1999. Design methods of molds plastic part with ribs, *Material for Mechanical Engg.*, 2(1), 33-65.

[8] W. Jian, L. Dexin, L. Shuliang, X. Zhenzhong and H. Hua. 2004. Study of steady measurements on intake port flow characteristics in a four-valve gasoline engine, *Trans. Chinese Society for Internal Combustion Engines*, 12, 183-184.

[9] W. Zongze and L. Shengguo. 2005. *Course Project for Machine Design*, Higher Education Press, Beijing.

[10] Z. Zhipei. 2001. The status and prospect of plastics for auto at home and abroad, *New Chemical Materials*, 3, 7-10.

[11] Z. Song and D. Jing min. 2003. Numerical simulation of flow field in intake system in internal combustion engine with tangent intake duct, *J. Harbin Institute of Tech.*, 35(1), 49-53.

[12] Z. Zhenwu, L. Shuliang, L. Dexin, Y. Jichao and, F. Hongqing. 2004. Study on the Test Technology of Steady State Flow of Port with Variable Pressure Drop, *Trans. Chinese Society for Internal Combustion Engines*, 22(1), 79-85.