Thermoelastic Analysis Of Disc Brake By Using ANSYS Software

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Abstract- *the brakes must be strong enough to stop the vehicle within a minimum distance in an emergency. The driver must have proper control over the vehicle during emergency braking and vehicle must not skid. The brakes must have good antedate characteristics their effectiveness should not decrease with prolonged application and thus it demand that the cooling of the brakes*

Should be very efficient. For the analyses are carried out for structural steel is used with two cyclic braking conditions to find structural steel material of the disc brakes is carried out for study to structural analysis of disc brake. A transient analysis for the thermo elastic contact problem of the disc brakes with heat generation is performed using the finite element analysis. To analyze the thermo elastic phenomenon occurring in the disc brakes, the occupied heat conduction and elastic equations are solved with contact problems. The numerical simulation for the thermo elastic behavior of disc brake is obtained in the repeated brake condition. The computational results are presented for the distribution of heat flux and temperature on each friction surface between the contacting bodies. Also, thermo elastic instability (TIE) phenomenon (the unstable growth of contact pressure and temperature) is investigated in the present study, and the influence of the material properties on the thermo elastic behaviors (the maximum temperature on the friction surfaces) is investigated to facilitate the conceptual design of the disc brake system. Based on these numerical results, the thermo elastic behaviors of the carbon-carbon composites with excellent mechanical properties are also discussed.

Keywords- thermo elastic instability, heat flux.

I. INTRODUCTION

A brake is a device by means of which artificial frictional resistance is applied to moving machine member, in order to stop the motion of a machine. In the process of performing this function, the brakes absorb either kinetic energy of the moving member or the potential energy given up by objects being lowered by hoists, elevators etc. The energy absorbed by brakes is dissipated in the form of heat. The disc brake is a wheel brake which slows rotation of the wheel by the friction caused by pushing brake pads against a brake disc with a set of calipers. The disc brake is usually made of structural steel, but may in some cases be made of composition such as reinforced carbon-carbon or ceramic matrix composition. This is associated to the Wheel or the axle. To stop the wheel, frictional material in the form of brake pads, mounted on a device called a brake caliper, is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Frictional causes the disc and attachment wheel to slower. Brakes convert motion to heat, and if the brakes get too hot, they become less effective, a phenomenally known as brake fade.

In the course of brake operation, frictional heat is dissipated mostly into pads and a disc, and an occasional uneven temperature distribution on the components could induce severe thermo elastic distortion of the disc. The thermal distortion of a normally flat surface into a highly deformed state, called thermo elastic transition. It sometimes occurs in a sequence of stable continuously related states s operating conditions change. At other times, however, the stable evolution behavior of the sliding system crosses a threshold whereupon a sudden change of contact conditions occurs as the result of instability. This invokes a feedback loop that comprises the localized elevation of frictional heating, the resultant localized bulging, a localized pressure increases as the result of bulging, and further elevation of frictional heating

As the result of the pressure increase. When this process leads to an accelerated change of contact pressure distribution, the unexpected hot roughness of thermal distortion may grow unstably under some conditions, resulting in local hot spots and leaving thermal cracks on the disc. This is known as thermo elastic instability (TEI). The thermo elastic instability phenomenon occurs more easily as the rotating speed of the disc increases. This region where the contact load is concentrated reaches very high temperatures, which cause deterioration in braking performance. Moreover, in the course of their presence on the disc, the passage of thermally distorted hot spots moving under the brake pads causes low-frequency brake vibration.

II. DISC BRAKE

A disc brake consists of a cast iron disc bolted to the wheel hub and a stationary housing called caliper. The caliper is connected to some stationary part of the vehicle like the axle casing or the stub axle as is cast in two parts each part containing a piston. In between each piston and the disc there is a friction pad held in position by retaining pins, spring plates etc. passages are drilled in the caliper for the fluid to enter or leave each housing. The passages are also connected to another one for bleeding. Each cylinder contains rubber-sealing ring between the cylinder and piston. When the brakes are applied, hydraulically actuated pistons move the friction pads in to contact with the rotating disc, applying equal and opposite forces on the disc. Due to the friction in between disc and pad surfaces, the kinetic energy of the rotating wheel is converted into heat, by which vehicle is to stop after a certain distance. On releasing the brakes the brakes the rubber-sealing ring acts as return spring and retract the pistons and the friction pads away from the disc.

a) Swinging caliper disc brake:

The caliper is hinged about a fulcrum pin and one of the friction pads is fixed to the caliper. The fluid under pressure presses the other pad against the disc to apply the brake. The reaction on the caliper causes it to move the fixed pad inward slightly applying equal pressure to the other side of the pads. The caliper automatically adjusts its position by swinging about the pin.

b) Sliding caliper disc brake:

These are two pistons between which the fluid under pressure is sent which presses one friction pad directly on to the disc where as the other pad is passed indirectly via the caliper.

III. PROBLEMS IN DISC BRAKE

In the course of brake operation, frictional heat is dissipated mostly into pads and a disc, and an occasional uneven temperature distribution on the components could induce severe thermo elastic distortion of the disc. The thermal distortion of a normally flat surface into a highly deformed state, called thermo elastic transition. It sometimes occurs in a sequence of stable continuously related states s operating conditions change. At other times, however, the stable evolution behavior of the sliding system crosses a threshold whereupon a sudden change of contact conditions occurs as the result of instability. This invokes a feedback loop that comprises the localized elevation of frictional heating, the resultant localized bulging, a localized pressure increases as the result of bulging, and further elevation of frictional heating as the result of the pressure increase. When this process leads to an accelerated change of contact pressure distribution, the unexpected hot roughness of thermal distortion may grow unstably under some conditions, resulting in local hot spots and leaving thermal cracks on the disc. This is known as thermo elastic instability (TEI). The thermo elastic instability phenomenon occurs more easily as the rotating speed of the disc increases. This region where the contact load is concentrated reaches very high temperatures, which cause deterioration in braking performance. Moreover, in the course of their presence on the disc, the passage of thermally distorted hot spots moving under the brake pads causes low-frequency brake vibration.

IV. FINITE ELEMENT ANALYSIS

The finite element method is numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in almost every industry. In more and more engineering situations today, we find that it is necessary to obtain approximate solutions to problem rather than exact closed form solution. It is not possible to obtain analytical mathematical solutions for many engineering problems. An analytical solutions is a mathematical expression that gives the values of the desired unknown quantity at any location in the body, as consequence it is valid for infinite number of location in the body. For problems involving complex material properties and boundary conditions, the engineer resorts to numerical methods that provide approximate, but acceptable solutions. The finite

a) Build The Model

In this step we specify the job name to define the element types, element real constants, material properties and model geometry element type. The ANSYS elements library contains over 80 different element types. A unique number and prefix identify each element type.

b) Material Properties

Young’s modulus must be defined for a static analysis. If we plan to apply inertia loads (such as gravity) we define mass properties such as density.

c) Solution

In this step we define the analysis type and options, apply loads and initiate the finite element solution. This involves three phases:

- Pre-processor phase
- Solution phase
- Post-processor phase

Pre-processor:

Pre processor has been developed so that the same program is available on micro, mini, super-mini and mainframe computer system. This slows easy transfer of models one system to other. Pre processor is an interactive model builder to prepare the FE (finite element) model and input data. The solution phase utilizes the input data developed by the pre processor, and prepares the solution according to the problem definition. It creates input files to the temperature etc. on the screen in the form of contours.

Geometrical definitions:

There are four different geometric entities in pre processor namely key points, lines, area and volumes. These entities can be used to obtain the geometric representation of the structure. All the entities are independent of other and have unique identification labels.

Model Generations:

With solid modeling we can describe the geometric boundaries of the model, establish controls over the size and desired shape of the elements and then instruct ANSYS program to generate all the nodes and elements automatically. By contrast, with the direct generation method, we determine the location of every node and size shape and connectivity of every element prior to defining these entities in the ANSYS model. Although, some automatic data generation is possible the direct generation method essentially a hands on numerical method that requires us to keep track of all the node numbers as we develop the finite element mesh. This detailed book keeping can become difficult for large models, giving scope for modeling errors. Solid modeling is usually more powerful and versatile than direct generation and is commonly preferred method of generating a model.

Mesh generation:

In the finite element analysis the basic concept is to analyze the structure, which is an assemblage of discrete pieces called elements, which are connected, together at a finite number of points called Nodes. Loading boundary conditions are then applied to these elements and nodes. A network of these elements is known as Mesh.

Finite element generation:

The maximum amount of time in a finite element analysis is spent on generating elements and nodal data. Pre processor allows the user to generate nodes and elements automatically at the same time allowing control over size and number of elements. There are various types of elements that can be mapped or generated on various geometric entities. The elements developed by various automatic element generation capabilities of pre processor can be checked element characteristics that may need to be verified before the finite element analysis for connectivity, distortion-index etc. Generally, automatic mesh generating capabilities of pre processor are used rather than defining the nodes individually. If required nodes can be defined easily by defining the allocations or by translating the existing nodes. Also on one can plot, delete, or search nodes.

Boundary conditions and loading:

After completion of the finite element model it has to constrain and load has to be applied to the model. User can define constraints and loads in various ways. This helps the user to keep track of load cases.

Model display:

During the construction and verification stages of the model it may be necessary to view it from different angles. It is useful to rotate the model with respect to the global system and view it from different angles. Pre processor offers these capabilities. By windowing feature pre processor allows the user to enlarge a specific area of the model for clarity and details. Pre processor also provides features like smoothness, scaling, regions, active set, etc for efficient model viewing and editing. Material defections:

All elements are defined by nodes, which have only their location defined. In the case of plate and shell elements there is no indication of thickness. This thickness can be given as element property

Solution:

The solution phase deals with the solution of the problem according to the problem definitions. All the tedious work of formulating and assembling of matrices are done by the computer and finally displacements are stress values are given as output. Some of the capabilities of the ANSYS are linear static analysis, non linear static analysis, transient dynamic analysis, etc.

Post- processor:

It is a powerful user- friendly post- processing program using interactive colour graphics. It has extensive plotting features for displaying the results obtained from the finite element analysis. One picture of the analysis results (i.e. the results in a visual form) can often reveal in seconds what would take an engineer hour to assess from a numerical output, say in tabular form. The engineer may also see the important aspects of the results that could be easily missed in a stack of numerical data.

V. PROCEDURE FOR ANSYS ANALYSIS

Static analysis is used to determine the displacements stresses, stains and forces in structures. Steady loading in response conditions are assumed. The kinds of loading that can be applied in a static analysis include externally applied forces and pressures, steady state inertial forces such as gravity or rotational velocity imposed (non-zero) displacements, temperatures (for thermal strain).

In the course of brake operation, frictional heat is dissipated mostly into pads and a disc, and an occasional uneven temperature distribution on the components could induce severe thermo elastic distortion of the disc. The thermal distortion of a normally flat surface into a highly deformed state, called thermo elastic transition. It sometimes occurs in a sequence of stable continuously related states s operating conditions change. At other times, however, the stable evolution behavior of the sliding system crosses a threshold whereupon a sudden change of contact conditions occurs as the result of instability. This invokes a feedback loop that comprises the localized elevation of frictional heating, the resultant localized bulging, a localized pressure increases as the result of bulging, and further elevation of frictional heating as the result of the pressure increase. When this process leads to an accelerated change of contact pressure distribution, the unexpected hot roughness of thermal distortion may grow unstably under some conditions, resulting in local hot spots and leaving thermal cracks on the disc. This is known as thermo elastic instability (TEI). The thermo elastic instability phenomenon occurs more easily as the rotating speed of the disc increases. This region where the contact load is concentrated reaches very high temperatures, which cause deterioration in braking performance. Moreover, in the course of their presence on the disc, the passage of thermally distorted hot spots moving under the brake pads causes low-frequency brake vibration.

VI. MODELING AND ANALYSIS

It is very difficult to exactly model the brake disc, in which there are still researches are going on to find out transient thermo elastic behavior of disc brake during braking applications. There is always a need of some assumptions to Model any complex geometry. These assumptions are made, keeping in mind the difficulties involved in the theoretical calculation and the importance of the parameters that are taken and those which are ignored. In modeling we always ignore the things that are of less importance and have little impact on the analysis. The assumptions are always made depending upon the details and accuracy required in modeling.

VII. SOLUTION

In the solution procedure, frontal solver is used. It involves

- After the individual element matrices are calculated, the solver reads in the degree of freedom (DOF) for the first element.
- The program eliminates any degrees of freedom that can be expressed in terms of the other DOF by writing an equation to the .TRI file. This process repeats for all the elements until all the degree of freedom have been eliminated.
- The term frequently used is the frontal solver is wave front. The wave front is the number of degrees of freedom retained by the solver while triangularization of the matrix.
- The nodal solution plot of temperature distribution in thermal analysis.
- Graph of the temperature variation with respect to the radial distance from the point of application of the heat flux. Graph of the temperature variation with respect to the time.

- The nodal solution plot of Stress distribution in structural analysis.

VIII.CONCLUSIONS

In order to improve the braking efficiency and provide greater stability to vehicle an investigation was carried out and the suitable hybrid composite material which is lighter than cast iron and has good Young’s modulus, Yield strength and density properties. The low weight, the hardness, the stable characteristics also in case of high pressure and temperature and resistance to thermal shock. In this paper, the transient thermo elastic analysis of disc brakes in repeated brake applications has been performed. ANSYS software is applied to the thermo elastic contact problem with frictional heat generation. Also, the fully implicit scheme is used to improve the accuracy of computations in the transient analysis. Through the axis symmetric disc brake model, the TEI (thermo elastic instability) phenomenon on each of the friction surfaces between the contacting bodies has been investigated. The hoop stress component in disc brakes has the largest compressive stress value and must be considered as a dominant stress component from the viewpoint of stress failure. The effects of the friction material properties on the contact ratio of friction surfaces are examined and the larger influential properties are found to be the thermal expansion coefficient and the elastic modulus.. It is observed that the isotropic disc brakes can provide better brake performance than the isotropic ones because of uniform and mild pressure distributions.

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