Thermal stresses in an IC engine cylinder

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Abstract

Her kommer det såkaldte "abstract" hvor du kort og klart beskriver øvelsens indhold og dine hovedresultater. Det skal ikke være særlig langt, men bør kunne læses som en selvstående tekst, der giver en potentiel læser et godt indtryk af indholdet af den følgende rapport.

1 Introduction

A cylinder in an IC engine is to be modelled and solved using the finite element method. The system will be simplified by a series of assumptions. We are interested in attaining the following informations.

1. Does the temperature distribution in the cylinder reach a steady state after a few cycles of operation?
2. How does the stress on the cylinder wall change as a function of time?
3. How much heat is stored in the cylinder after reaching steady state and how much is lost per cycle?

2 Problem Analysis

2.1 Involved Physics

A hollow cylinder expands and contracts due to changing temperatures inside it. Temperatures vary on a range of $950K$ in a cyclic fashion. Temperatures changes produces thermal stress. The cylinder is cooled from the outside by a coolant. The cooling rate is proportional to the temperature difference of the coolant and the cylinder.

2.2 Geometry Reduction

The geometry can be reduced to a 2D axisymmetrical setup. This can be seen by drawing a cross-section of the cylinder along it's vertical axis. The full cylinder can then be drawn by rotation of the plane around the vertical axis.

2.3 Simplifying assumptions

The cooling rate is assumed to be discreet. It is constant in two domains and changes discreetly at their boundaries. It is also assumed that the cylinder is constrained on it's outward surface. This means that the cylinder can only expand inwards. Further the temperature is modelled to change discreetly between the three phases of the engine cycle. Considering the thermal expansion we assume the expansion to be elastic, since a cylinder that undergoes plastic deformations during operation is useless. The strain orthogonal to the radius is assumed to be very small since the cylinder can't expand in this direction. We therefore have a situation of plane strain.

2.4 Boundary conditions

We assume that the cylinder can not expand upwards or downwards and that heat can not flow in these directions. We do this, because the cylinder is connected to other engine parts which operate at essentially the same temperature. Therefore heat doesn't flow because there is no temperature difference. The outward surface is fully mechanically constrained, but it allows for heat flow. The inward surface is free to expand and contract. It's temperature is given by the current phase of the engine cycle.

3 Mathematical Models

At the interfaces the heat flow is modelled by the following formula, where ΔT is the temperature difference over the interface and h the heat transfer coefficient.

$$q = -h\Delta Te$$

The cylinder expand according to the linear expansion model:

$$\epsilon_{\text{thermal}} = \frac{\Delta L}{L} = \alpha_L \Delta T$$

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4 Numerical Model

Her beskriver du kort hvilket apparatur du har anvendt. Blokdiagrammer er fine her. Hvis det er relevant, kan du "copy-paste" fra noterne, der i pdf-form ligger på kursets hjemmeside. Her kan du bruge Adobes "Snapshot Tool". Det er ofte tilstrækkeligt at henvise til noterne [**?**] med sideangivelse. Tegninger kan laves i f.eks. INKSCAPE [**?**].

4.1 Numerical Results

Denne figur fylder to spalter.

Husk at angive usikkerheden på de rå data, eventuelt som et skøn.

4.2 Databehandling

Her kommer en beskrivelse af databehandlingen. Hvilke udregninger har du foretaget og hvad har du antaget:

$$A = \sum_i (n - \frac{a_i}{b_i}) \tag{1}$$

Her er $a = (0.264 \pm 0.009)$ MeV/kanal [**?**] og ydermere er $b = (9 \pm 8)$ MeV/kanal . Da korrelationskoefficienten er bestemt til R = 0.996 er det en rimelig approksimation at anvende en lineær sammenhæng. Se evt. [**?**] for mere information om enheder.

5 Discussion

Her skriver du kort hvad du kan konkludere efter at have gennemført øvelsen. For denne templete kan man f.eks. konkludere at der er en del "warnings" som ikke betyder noget.

Bibliography

[1] Eksperimentelle øvelser i fysik, øvelsesvejledninger efteråret 2010, IFA, Aarhus Universitet

[2] Se: www.inkscape.com

[3] Manual for siunitx: ftp://ftp.tex.ac.uk/tex-archive/macros/latex/exptl/siunitx/siunitx.pdf

[4] Daleifs bog om LaTeX. Bogen kan findes her http://imf.au.dk/system/latex/bog/.