CRACK EFFECTS IN ROTORDYNAMICS

Guest editors:

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Cracked rotating shafts have been the object of studies and investigations since the 60's, it seems that the first paper on cracked structures has been published in 1957, therefore now we have a story lasting almost 50 years. Important achievements have been made during these years, the knowledge of the dynamical behaviour of cracked shafts has allowed to recognize the presence of a crack and to stop the cracked shafts in time before catastrophic failures. Close inspections revealed that in many shafts the crack had already propagated up to a depth of almost 50% of the diameter, which is obviously a very critical situation. Bearing in mind the fact that it is generally believed that propagating velocity increases exponentially, in many of these cases some days of operation would have been sufficient to provoke a catastrophic failure, with the loss of the complete machine train and high risks for people and other equipment. In some cases instead the machines burst, generating catastrophic failures with heavy damages to the plants. Very high costs were involved in the reconstruction of the machines and of the complete plant, as well as in the lost production for several years.
When a crack is discovered in time, the cracked rotor can be substituted by a spare rotor in few days or weeks, with affordable economic losses.
This situation explains the increasing interest in behaviour of cracks in general and of cracked shafts in particular. Starting from the 80's up to nowadays researchers from everywhere in the world have contributed with papers addressing different topics related to cracks in rotating shafts
The total number of papers is probably now close to 1000, and is still increasing. Anyhow only very few papers present experimental results and generally these are related to very simple models, like the Jeffcott rotor. Seldom these results can be extended to real rotors.

Giving this situation, we have felt that it would be useful to dedicate a special issue to the state of art of modelling the dynamical behaviour of cracked rotors, including the inverse problem of identification of cracks in rotating machinery.
Therefore we have invited some authors among the very rich quantity of different contributors to present a specific topic in the wide field of all the different aspects of cracked rotors. Finally also a paper authored by us covers some topics which are not covered here (or only partially covered) by the other authors.

The first paper, by Chris A. Papadopoulos, is dedicated to the approach based on fracture mechanics for evaluating the change in stiffness or in compliance of an axisymmetric shaft due to presence of a transverse crack, and to the development of this approach during the last three decades. Also the so called coupling effects, i. e. the excitation of torsional and axial vibrations due to the presence of the crack and of bending loads, has been modelled by this approach. This approach has been used by almost all researchers who have contributed in this field, with only few but significant exceptions.

The second paper, by Robert Gasch, is dedicated to the main characteristics of the behaviour of a simple model of cracked shaft. This analysis is made with a simple model of the crack (the “hinge model”) which allows to find analytically almost all behaviours related to the excitation of flexural vibrations in cracked shafts, which contributed significantly to the understanding of the peculiar behaviours of cracked rotors.

The third paper, by Yukio Ishida, is dedicated to the description of industrial machine case histories, which gives insight to the frequency and dangerousness of crack events in rotating machinery, and to some non linear effects shown on simple Jeffcott rotor model by analytical/numerical approach.

The fourth paper, by Carlo Stoisser and Sylvie Audebert of Electricité of France (EDF) is dedicated to a different numerical approach for modelling with high accuracy the effect of a crack, suitable for any crack shape, depth and propagation direction, which has been developed and widely tested experimentally in one of the biggest rotor test rigs dedicated to cracked rotors tests.

The fifth paper, by A.S. Sekhar, is dedicated to the effects of some more unusual occurrences in cracks, like the development of multiple cracks, and to the way they could be modelled and detected.

Finally the last paper, authored by us, covers some peculiar aspects that have not been analysed completely by other authors, such as:

- the accurate modelling of the breathing behaviour, that is the gradually opening and closing of the crack during one rotation of the shaft. This behaviour is influenced also by possible thermal transients which could occur during normal operating conditions of industrial machines,
- the analysis of the effects of a crack having an helical development instead of a planar transverse propagation and
- the non linear effects which could occur in industrial machines.

A rich, but not exhaustive bibliography is spread over the references of the different papers.

Almost all topics related to the behaviour of cracked rotors have been covered, is there still place and need for further investigations? According to our opinion higher accuracy could be required and obtained in some of the topics, but the overall behaviour of rotating cracked shafts is well assessed and does not need further developments. The local behaviour of cracks in rotating shafts instead, involving the fracture mechanics approach could require further investigations. There are two weak points on which the knowledge could be improved: one is the prediction of propagation velocity and residual life estimation from static loads and from dynamical actual behaviour of cracked shafts, and the second is the definition of the measures that could be taken for reducing or stopping the propagation velocity. This knowledge could help in avoiding wrong decisions about removal from service of shafts with suspected cracks.

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