Plan for the scientific work

Background

Ever since the industrial revolution rotating machinery has been crucial in the society. Sweden have a strong industrial background with famous engineers such as Gustav de Laval, Birger and Fredrik Ljungström who initiated the field of turbo machinery by the development of the separator, axial steam turbine, radial steam turbine and the screw compressor. From these innovations several large successful Swedish companies have been developed whose key competence is rotating machines.

During my time at the industry, I worked with rotating machinery and become interested in dynamics. After three years I got the opportunity to become a PhD student at Luleå Technical University. The research area was chaos and nonlinear dynamics in vibro-impacting mechanical systems. Nonlinear dynamics was an interesting research area but it was by that time difficult to find industrial interest for continuing the research. Therefore I took a work at SICOMP in solid mechanics of composites during seven years before I got a position as Senior Lecturer in Solid Mechanics at LTU. After two years of teaching, I was ready for scientific work. It was obvious that the area should be dynamics and after a review of the national research in dynamics, it became clear that rotor dynamics was an area of great potential. In Sweden it was only one group in Linköping working in the research area and they had decided to not continue with rotor dynamics. My industrial background also gave me a deep insight in the industrial problems of rotating machinery and hence it was easy for me to get in contact with industrial partners. In rotor dynamics there are several nonlinearities such as contact, bearings, fluid interaction and electromagnetic interaction that can not be avoided. Therefore my own research area of nonlinear dynamics is also useful in this field.

My first PhD student worked on development of rotor models for wood chip refiners. The project was financed by our excellence centre “Polhem” at LTU. My second PhD student worked on optimisation of turbo generators and gas turbine rotor systems. The project was financed with 800kkr/year by Alstom Sweden. The third PhD student came from Vattenfall and he was financed by the company to work 50% with research. We found that the area was unexplored and there was a large potential to avoid failures if we could develop better dynamical models of the system. Since then hydropower research has been the strongest growing area of my research. During 2006 a Swedish centre was initiated for hydropower research (SVC) and I became one of the five financed senior research leaders with responsibility for the development of rotor dynamics. The competence we have built in hydro power technology can easily be applied to new fields of mechanics. In the sections below I will describe the potential of developing the field in the future.

Scientific work

During my PhD studies I analysed nonlinear dynamics and chaos in vibro-impacting systems. By that time, it was of interest to evaluate if chaos was something that the industry had to consider in design and if there were any possibilities to use chaos in industrial applications. Today it is clear that nonlinear phenomena can occur in mechanical systems, but it can often be avoided by a careful design. The common question today is therefore how to avoid nonlinear phenomena. In rotating machines there are several nonlinearities that can not be avoided. Therefore nonlinear phenomena have to be considered in the design and there is a need to develop effective tools to handle these situations.

Since I came back to the University rotor dynamics has been my research field. Together with my PhD students we have worked on

- Impact problems
- Optimisation of rotating turbo machines
- Wood fibre defibrators
- Cutting dynamics
- Hydro power rotors
- Development of new tools to analyse nonlinear systems

It is in the field of hydro power rotors that we have published most of the papers. In this field we are today strong and we will continue to expand our activities in this area. In our research we have worked with the rotors interaction with electromagnetic field, bearings and fluid. Through collaboration with the fluid mechanics (LTU) and machine element (LTU), fluid mechanics (Chalmers) and electricity (UU) we have been working with models of the interaction in order to develop better rotor dynamic models. I am also working with Prof Matthew Cartmell at Glasgow University in order to develop a similar research group in Scotland. Professor Cartmell is a well known scientist in non-linear dynamics and together with him I can develop our competence further. The competence we have achieved in hydropower technology can be applied to other industrial fields and I see great opportunities to develop these new areas.

Rotor dynamics in hydro power units

Since 2001 hydropower has been my strongest research field. These machines are at first sight quasi static since the rotational speed is normally only 2-10 hz. But, due to the large size (up to 1000 metric tons) and generator diameters up to ten meter the gyroscopic effect is essential in the analysis of these machines. Normally, most of the rotor models are developed for horizontal machines but in hydro power applications the machines are normally vertical. The size and the vertical alignment give these machines several problems which have not been studied earlier.

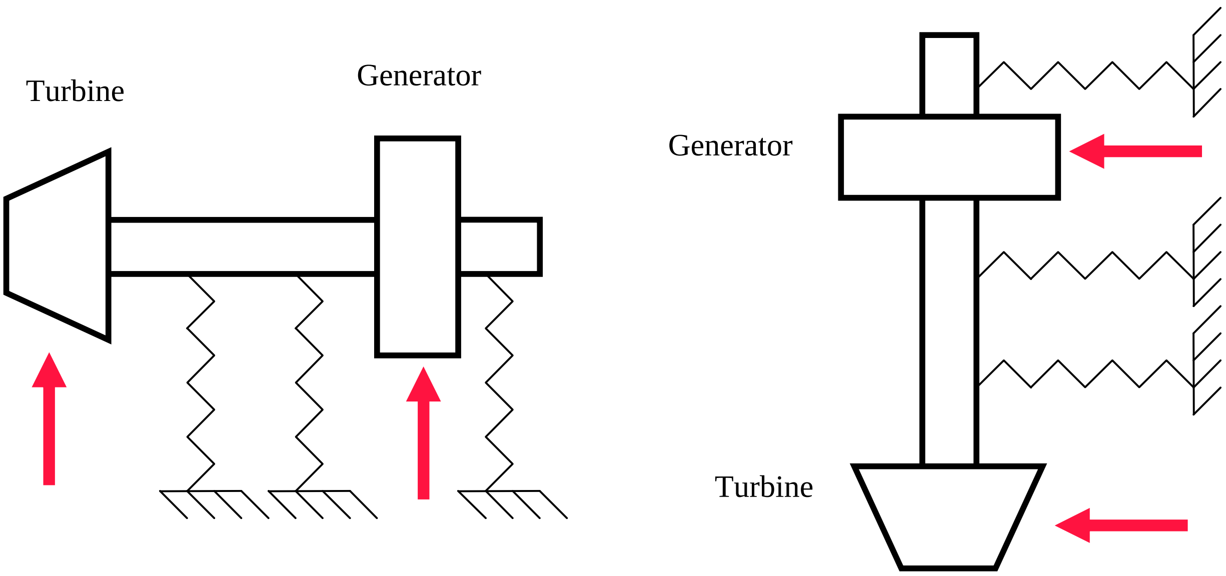

Figure 1, To the left an ordinary horizontal machine and to the right a typical hydro power rotor. Red arrows marks forces from fluid and electro magnetic fields.

In figure 1 an ordinary rotating machine is shown to the left and a typical hydropower rotor to the right. In a horizontal machine the gravity results in known forces on the bearings and hence the baring properties can be estimated with good accuracy. The generator is small and the relative air gap is large which results in a less sensitive rotor due to electro magnetic forces. In a typical hydro power rotor the vertical alignment results in unknown bearing forces and thereby unknown properties of the stiffness and damping. The size of the generator is large and the air gap is small which results in strong electromagnetic interaction. The shape deviation of the generator is also relatively large which results in periodic excitations of the rotor. For both cases the fluid rotor interaction is unknown but due to the density of the water we have in hydropower applications a strong interaction between the fluid and the rotating structure.

In our research we have studied the rotor interaction with the magnetic field due to eccentricity and shape deviations of the rotor. Due to the damper windings, we have found that the electromagnetic stiffness will depend on the whirling frequency. In an ongoing project together with Uppsala University we are developing new electromagnetic models and rotor dynamical analysis methods to evaluate how the stability of the rotor is influenced by these new forces. The influence of shape deviations has also been studied together with UU and we have found that both forward and backward whirl frequencies can be excited when the shape is not perfectly round. Better electromagnetic models are however essential in order to go further in the analysis.

The rotor-bearing interaction is studied in several ongoing projects. We have earlier performed measurements in order to estimates the stiffness of the bearings. It is clear that the models are far more complex than the constant stiffness model used today. Therefore several projects are working on development of bearing models and rotor dynamical evaluation of these new models.

Fluid rotor interaction has been studied in some projects together with Chalmers and fluid mechanics at LTU. The target of these first numerical experiments was to find if simulation tools can be used to find the fluid forces and also the added mass and damping properties due to fluid interaction. The result has been promising but far more studies are needed before new models can be developed.

Several measuring techniques has been developed in order to find forces acting on the rotor. Today we are running a large project (28 million SEK) where a real power unit is instrumented with over 250 gages. From these measurements we expect to find detailed information on all forces acting on the system. The results will be used to evaluate developed models.

Vision

The vision of my research is to become a strong scientist in the area of multi-physics in rotating machinery. The competence from hydro power research will be applied to other industrial applications. By international collaboration I expect to develop useful methods to design rotating machinery when non-linearities can not be neglected.

Strategy

Today my research is mainly focused on hydro power rotors. However, the developed methods in Hydropower can be applied to other industrial areas. The aim is therefore to expand the activities to other areas. Below, I have listed some strategic areas where it should be possible to get funds for research projects.

Energy systems
- Hydropower (SVC, ELEKTRA, British hydro power industry together with Mathew Cartmell Glasgow Univeristy)
- Wind power (VINDFORSK, Power industry, EU)
- Nuclear power (Power industry)

Nonlinear dynamics
- Contact problems (VR, EU together with Mathew Cartmell Glasgow University)
- Useful design tools (VR, EU, together with Mathew Cartmell Glasgow University)

Process industry
- Fan& pumps (Svenska fläkt, IVT, SKF)
- Separators (Alfa Laval, 3Nine)
- Cutting dynamics (Sandvik, Volvo Aero)

Vehicle & aero
- Whole engine models (Volvo Aero, NFFP)
- Drive train (Volvo car, Volvo truck, Scania)

Wind power is today a active research area in Sweden. But so far we have not succeded to get funds for mechanical research. I have concluded that icing problems and operation in cold climates could be an area where I could develop strong research competence. It is also likely that rotor dynamics and solid mechanics of nuclear power plants can be funded. The machines in Sweden are now old and reliability is essential for the power industry. It is therefore likely that PhD projects could be initiated in this area.

The work with Glasgow University will continue and we will have some meetings with the Scottish hydro power industry. I expect that our cooperation will result in projects by the end of the year.

Application will also be submitted to VR for basic nonlinear research.

I have good contact with Volvo Aero and we are looking into possibilities to initiate new project on whole engine modelling. In this case my problem has been to find a research question that can be of scientific interest. The reason is that the dynamical competence is found at the industry and therefore it is difficult to find the state of the art.

From the other industrial partners it is normally very difficult to get fully financed PhD students. I have to find suitable calls from national funds in order to get a project. Another alternative is to find a group of companies that have similar questions. So far I am just keeping contacts and waiting for a possibility.

Methods

The methodology in my research has followed a clear strategy. Developed models must be general and easily adapted to existing as well as new systems developed in the future. Of course, all theoretical models are models of real components and the obtained results can always be questioned if they reflect a real behaviour. It is therefore important to verify the developed models with measurements of the behaviour of real components.
The models in my research are derived by applying the well known scientific method called Newton’s second law or in some cases Lagranges equation. My aim is to validate all models by laboratory experiments or by on-site measurements on real machines.