Simulating Dynamic Behaviour of Weaving Machines

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Abstract

Inside the SULZER Corporation the SULZER INNOTEC group „Machine Dynamics" is engaged in the numerical simulation of mechanical multibody systems.

Such simulations are increasingly used by INNOTEC for the analysis and solution of problems on behalf of the SULZER product divisions or for external customers.

To date MSS has mainly been used for the analysis of problems dealing with the dynamics of weaving machines (Product Division SULZER RÜTI).

The mechanical weaving process can be characterised by high masses which have to move through their working strokes during small motion periods. The resulting positive and negative accelerations cause high inertia forces and torques, as well as high instantaneous power consumption. These forces, torques and mechanical reactive powers produce a lot of negative effects on the dynamic behaviour of a weaving machine.

Reduction of dynamic forces and the thereby induced emissions is an important goal in the mechanical development of weaving machines. In the development process a MSS-Software like ADAMS can be employed as an universal tool. At different stages of the development and construction process it is used for investigations to answer questions that originate from different working areas.

Parametric modelling using ADAMS/View permits the building of standard models. These models are applied to alternative configurations derived from the basic machine without a lot of modifications.

With increasing weft insertion rate the spectral components of the inertia forces are shifted to frequencies, where bearing structures and many subassemblies no longer behave like rigid bodies and can be caused to resonate. For this reasons elastic modelling and knowledge of system natural oscillations are of importance. Therefore ADAMS/FEA and ADAMS/Linear are of increasing significance.

1 PRESENTATION

1.1 SULZER

The aim of SULZER is to be a market-oriented, internationally leading Technology Corporation.

SULZER is active in the following sustainable markets:

- Weaving Machinery
- Reciprocating Compressors
- Pumps
- Thermal Turbomachinery
- Locomotives
- Plant an Building Services
- Medical Technology
- Process Engineering
- Thermal Power Systems
- Surface Technology
- Hydraulics

1.2 SULZER INNOTEC

SULZER INNOTEC is the Central Research and Development Centre of the SULZER Technology Corporation.

Core technologies constitute the basis for the services provided by SULZER INNOTEC. The core technologies are selected in view of the long term requirements of the SULZER Corporation and also constitute the basis for the INNOTEC structure.

Developmet work, calculations, engineering, fabrication and consulting services, known as Services and Consulting, are effected on direct job terms.

Also longer-termed joint research and development projects with the SULZER product divisions and long-termed corporate projects are effected.

1.3 Machine Dynamics (MDY)

Within SULZER INNOTEC the group known as „Machine Dynamics" (MDY) is using MSS technologies. Two members of the staff are working on projects dealing with numerical machine dynamics. Other members are working in the field of experimental research, which means doing measurements.

The ADAMS product line has been used since 1989.

The following products are installed on a workstation HP-Apollo Series 720:

- ADAMS/Solver
- ADAMS/View
- ADAMS/Linear
- ADAMS/FEA (Interface to ANSYS)

The FEA-Interface is used together with staff from the group known as „Structural Mechanics".

The SULZER product divisions constitute the main customers in the field of MSS:

- SULZER RÜTI (Weaving Machines)
- SLM (Locomotives)
- MSB (Reciprocating Compressors)

Projects have also been carried out for external customers such as:

- SIG (Packaging Machines)
- Bucher (Agricultural Machines)
- Bühler (Corn Mills)

To date, MSS has mainly been used in the field of weaving machines.

2 WEAVING MACHINES

2.1 General Weaving Process

Generally the weaving process can be divided into a number of partial processes. From a machine dynamics point of view, the main processes are the following:

- Shedding Mechanism (Shed formation)
- Weft Insertion
- Sley Drive (Beat up of Weft)

According to the weft material being woven or to the desired cloth, different weft insertion systems are offered:

- projectile
- rapier
- air-jet

2.2 Dynamic of Weaving Process

The individual partial processes have common dynamic properties.

One main characteristic is the use of relative high masses (compared to the mass of weft) which have to move through their working strokes in short periods of time. The resulting positive and negative accelerations cause high inertia forces and torques, as well as high instantaneous power consumption.

The predominating dynamic forces cause high alternating stresses in the various components, in the bearing structure (frame) and the joining elements.

Depending on the stiffness of the machine-mounting, the high dynamic forces cause either high machine vibrations or high foot-forces.

High machine vibrations produce negative effects on the quality of the cloth and on the operation of the machine. Additionally high vibrations impair the reliability of numerous attached parts.

The noise which is induced by the vibrations can damage the health of the operating personnel or annoy people in the neighbourhood.

High dynamic foot forces have negative effects on the dynamic behaviour of the building and on the neighbourhood of the weaving mill.

With increasing weft insertion rate, that is with increasing speed, the spectral components of the inertia forces are shifted to frequencies at which the bearing structure and many subassemblies no longer behave like rigid bodies and they can become excited to a state where they resonate.

Additionally the whole drive train is loaded by high mechanical reactive power which leads to highly non-uniform speed and irregular load on the main electric motor.

2.3 Using ADAMS at different Stages of the Development and Construction Process

Due to the manifold dynamic problems simulation tools - especially those for MSS - are used at different stages of the development and construction process of a weaving machine:

- Concept design and preliminary studies of future layouts to proof their functionality and to quantify the dynamic loads
- Design verification of existing layouts to proof its structural integrity and dimensioning and to locate the sources of possible component failure
- Proof the capability of existing layouts for planned increase of power (increase of speed)
- Further development and optimisation of existing layouts

2.4 Using ADAMS on different Task Areas

Because the dynamic problems also cover different task areas, there are manifold requirements place on the models since they must be usable to yield answers to different questions:

- Foundation planning and sales department are interested in the emissions of the machines (like foot-forces and frame vibrations)
- Construction engineers take an interest in the internal forces and the deformations of the parts as well as in the bearing loads
- To design the drive train a knowledge of the energy circuit inside the whole drive train is important. This knowledge permits the layout of the flywheel mass, taking into account the non-uniform speed, the starting behaviour and the motor load. Additionally the main motor and its control system can also be designed, taking into account the dynamic behaviour of the complete drive train.

These different interests sometimes lead to conflicts. Balancing of masses, for example, reduces the emissions - like foot forces - but increases internal loads such as cam forces and driving torques. In such cases, a compromise has to be found together with the groups concerned.

2.5 Modelling Process

To cover the manifold interests and questions coming from the various task groups, the simulation models are built up from partial modules of the passive frame and the active functional groups supported by the frame. The modules can then be used individually, or combined to build up more comprehensive models.

2.5.1 Modelling of the Frame

The elastic frame is modelled in ADAMS/View using standard ADAMS elements. To facilitate universal use, especially for different widths, the frame model is parametrized.

Some stiffnesses used in the frame model can not be easily quantified. Therefore the model is calibrated by a Modal Analysis.

A Modal Analysis, which is performed on the real structure, yields mode shapes together with the associated natural frequencies and modal damping.

To calibrate the model, the experimental results are compared with the results calculated for the model using ADAMS/Linear. „Trial and Error" is used to adjust the stiffnesses of the ADAMS-elements being used until the experimental and the analytical results coincide.

In cases where the real structure does not exist, the model can be built up and calibrated using the ANSYS FEA-Program. The mass and stiffness matrices of the structure, respectively its modal descriptions are calculated by ANSYS and imported to ADAMS by the use of the ADAMS/FEA-Interface. This interfaced is currently being tested.

A direct import of experimental modal data could avoid modelling and calibration of an ADAMS- or an ANSYS-model.

2.5.2 Modelling of Functional Groups

The various functional groups are also modelled in ADAMS/View using standard elements.

Due to elasticity and the expected excitation-frequencies, most parts can not be considered as rigid bodies. The stiffnesses of such parts are modelled using standard elastic elements.

Because component geometries become more and more complicated, their stiffnesses can no longer be modelled in this easy way. Stiffness properties, therefore, must be determined by an FEA-analysis. The resulting matrices or modes are imported to ADAMS by the use of the ADAMS/FEA-Interface.

2.6 Quality of Models

A number of parameters used in the different models can not be quantified analytically. Therefore experimental verification of data will still be necessary to proof the quality of the simulation models.

With shedding motion, for example, the exact influence of the cloth is unknown. There are configurations at which the forces induced by the cloth predominate the inertia forces. In future such effects must increasingly be taken into account, so that simulations and measurements are in better agreement. If the forces induced by the cloth can be described analytically they can be included via a FORTRAN-subroutine.

Quantification of damping is another general problem; not only in the field of weaving machines, especially when some frequency components of the excitation forces are near to a systems natural frequency. In such cases the results are predominated by the modal damping of the excited free vibration.

Although quantification of damping will always be difficult, in many cases the use of ADAMS/Linear provides a better understanding of the dynamic system. The natural frequencies of the linearized model determine operating ranges at which resonances are to be expected. The corresponding modal damping indicates the sharpness or the step-up of the resonances.

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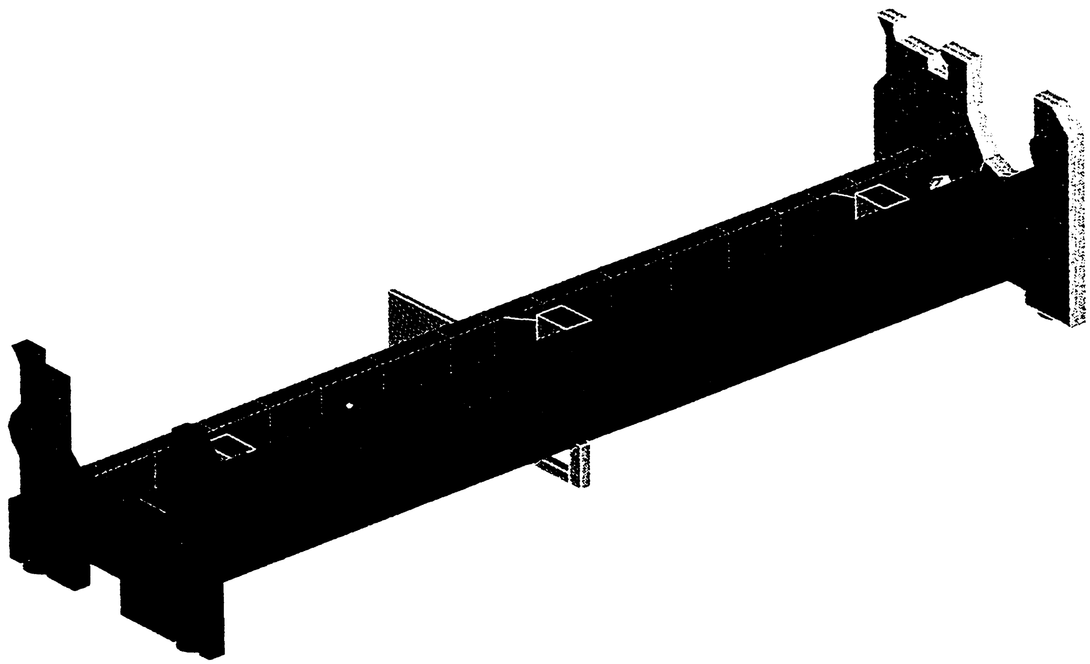

Figure 1: Frame of a Projectile Weaving Machine

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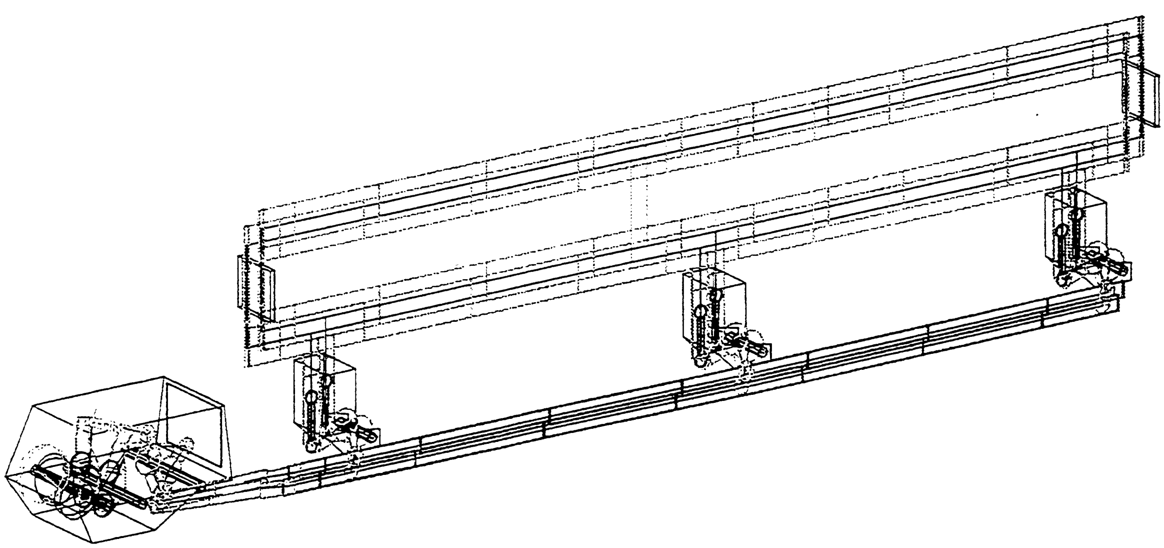

Figure 2: Shedding Mechanism of a Projectile Weaving Machine

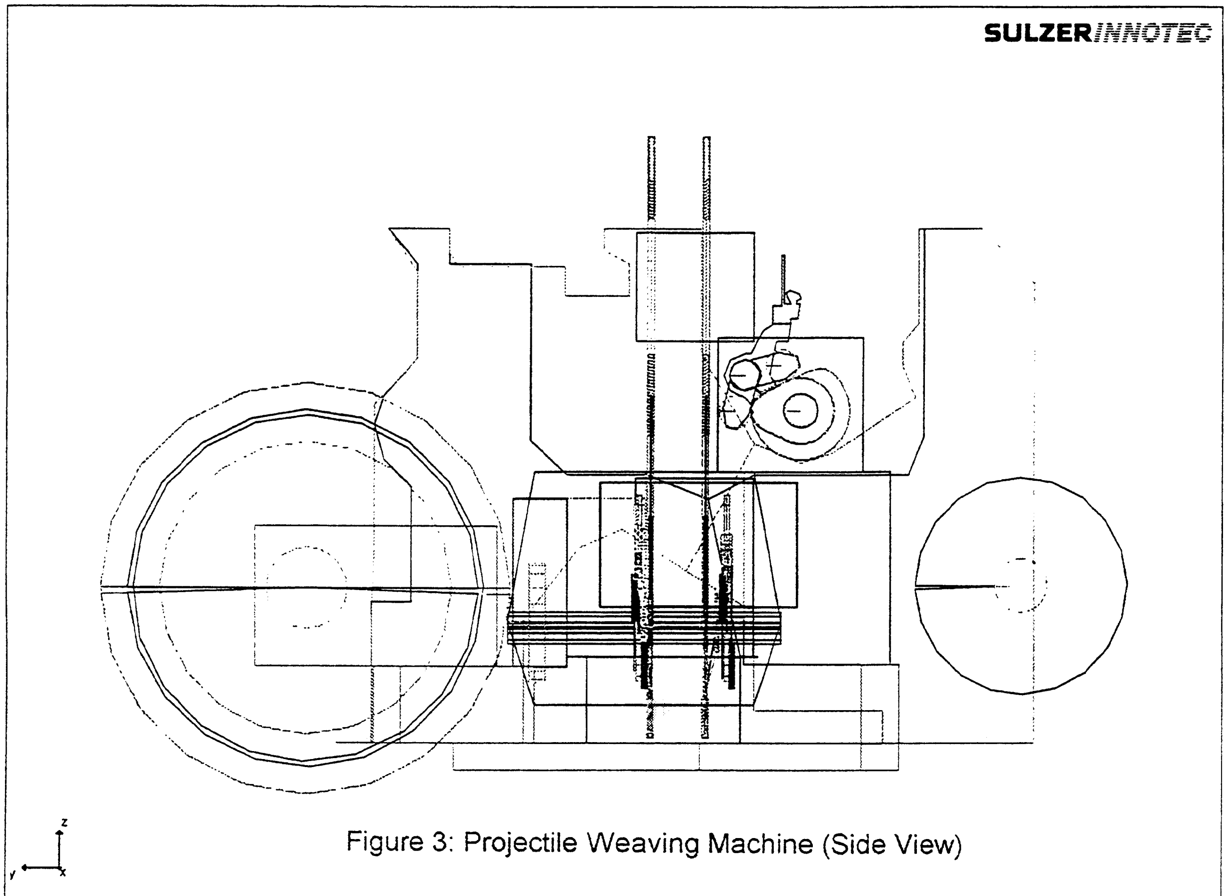

Figure 3: Projectile Weaving Machine (Side View)

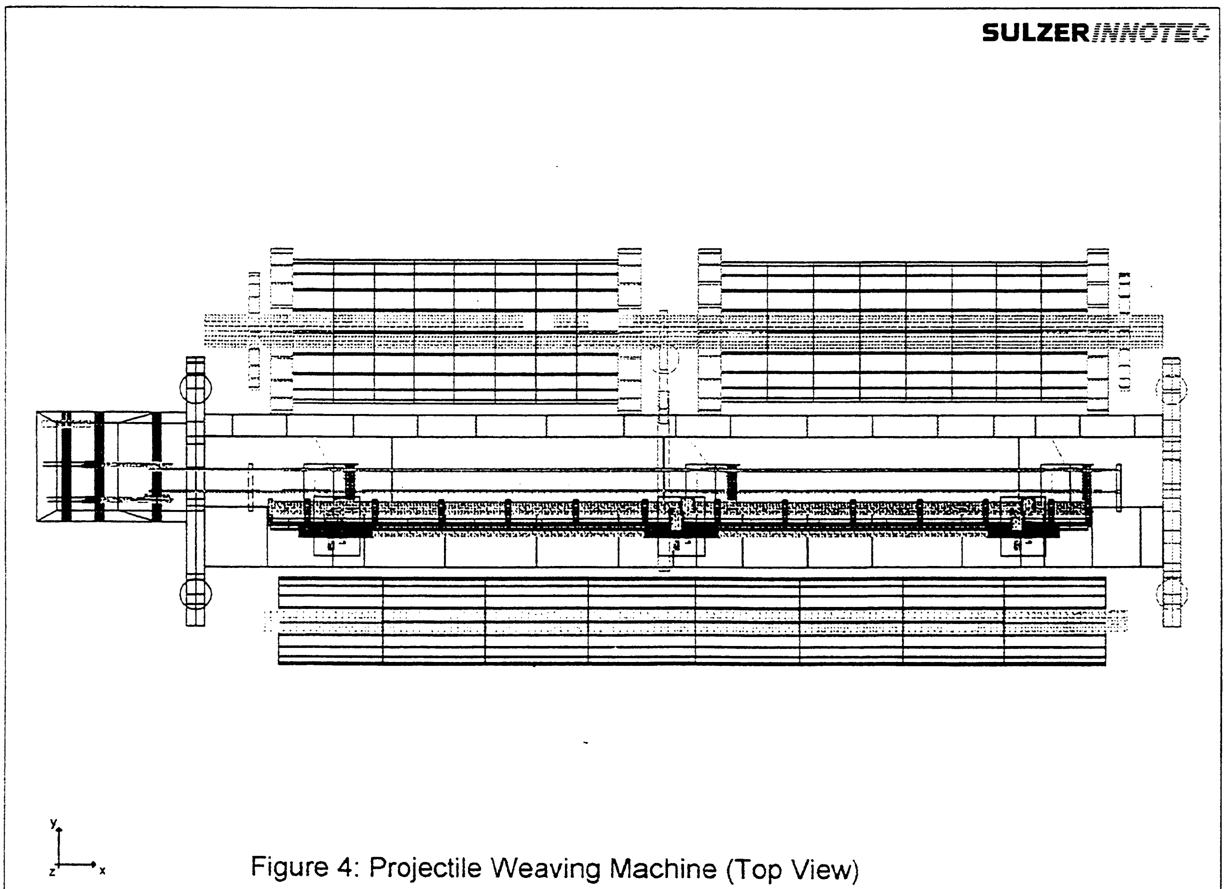

Figure 4: Projectile Weaving Machine (Top View)

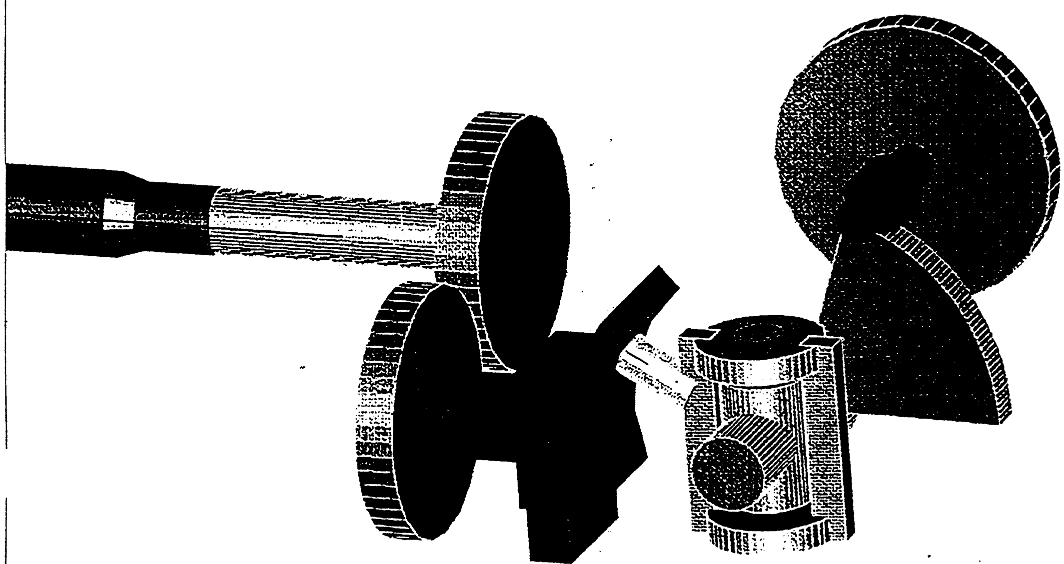

Figure 5: Spatial Crank Gear of a Rapier Weaving Machine

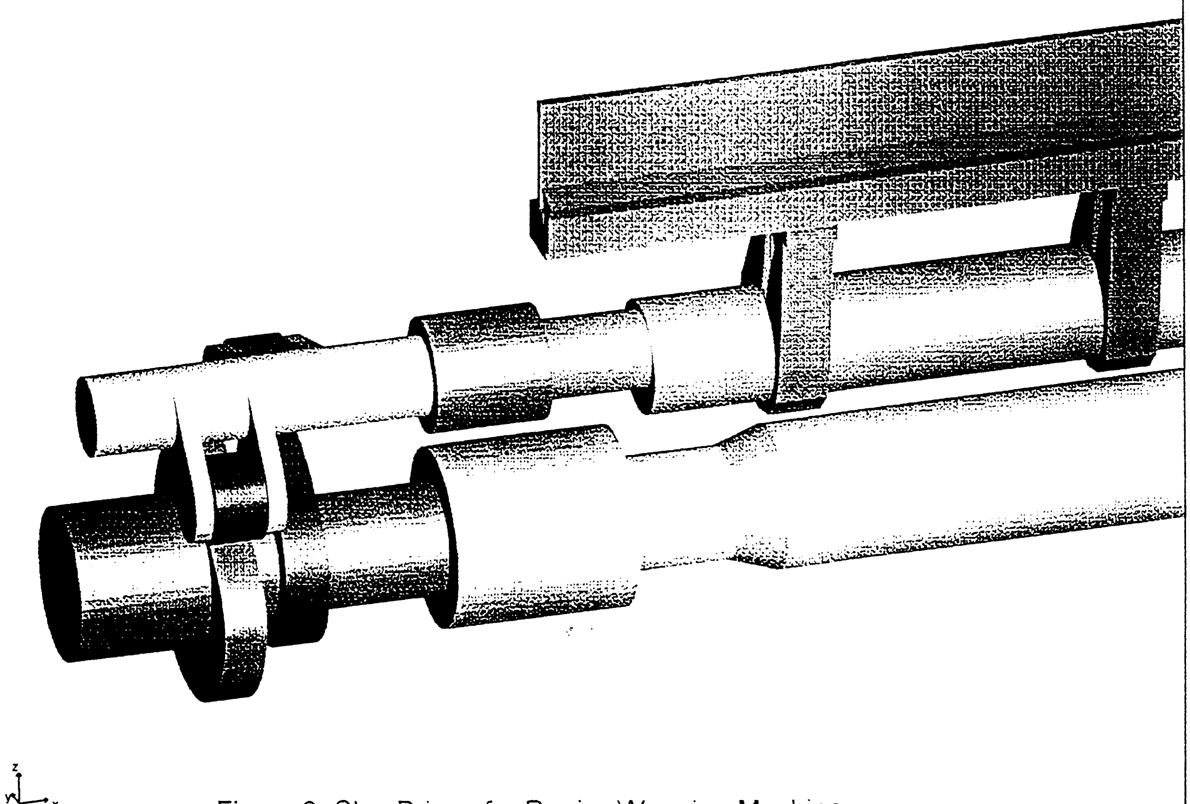

Figure 6: Sley Drive of a Rapier Weaving Machine

10th European ADAMS Users´ Conference Agenda

Wednesday, November 15th

08:30

- **"A link Between ADAMS and the Bath Constraint Modeller"**
  B. R. Twyman, University of Bath & S. Biggs, Mechanical Dynamics Ltd.
- **"Numerical Methods in ADAMS"**
  M. Steigerwald, Mechanical Dynamics Inc.
- **"ADAMS Powertrain Chain Drive System"**
  Yeongchin Lin, Ph. D., Mechanical Dynamics, Inc., Sam Mc. Donald, Mechanical Dynamics Inc
- **"ADAMS Simulation as a Base in Designing of Modern Automated Cranes"**
  Dr. Eng. M. Georgijevic, Fac. of Technical Sciences, Novi Sad

10:30 Coffee Break

11:00

- **"ADAMS/Rail - Verifications and Applications"**
  M. Busstra, Nederlandse Spoorwegen
- **"A Detailed Shock Absorber Model for Full Vehicle Simulation"**
  Dr. R. Sonnenburg, R. Lang, Fichtel & Sachs
- **"Vehicle Tyre Interface - Requirements, Concepts and Design"**
  K. Wolperding, Volkswagen AG, A. Fandré, VW-Gedas, Prof. Dr. Ing. Ch. Oertel, FH Köthen Anhalt

12:30 Lunchbuffet

14:00

- **"Step by Step Simulation of the Operating Mechanism of a Circuit-Breaker from a Simple to a Realistic Model with the Help of ADAMS"**
  Dr.-Ing. M. Vix, Sprecher + Schuh AG
- **"Investigation of Origin and Enlargement of Out-Of-Round Phenomenas in High Speed ICE-Wheelsets"**
  B. Morys, Dr.-Ing. H.-B. Kuntze, Dr.-Ing. U. Hirsch, Fraunhofer Institut IITB
- **"Impact Biomechanics Using ADAMS Android"**
  L. Minesso & A. Rimoldi, Dipartimento Di Ingegneria Aerospaziale, Politecnico Di Milano

15:30 Coffee Break

16:00

- **"Coupled Simulation of a Hydromechanical System"**
  A. Rouvinen, H. Handroos, & A. Mikkola, Lappeenranta University of Technology
- **"Driver Modeling in ADAMS"**
  Dr. A. Riedel, IPG
- **"Vibration Control of a Lightweight Flexible Robot: Numerical Simulation"**
  G. Ferrarotti, A. Somà, Dipartimento di Meccanica, Politecnico di Torino