Step by step simulation of the operating mechanism of a circuit breaker from a simple to a realistic model with the help of ADAMS.

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1995 ADAMS User Conference
14-15 November 1995
Frankfurt Niederrad; Germany

1. Introduction

Circuit breakers are electro-mechanical devices for the protection of loads like electrical motors or distribution networks against overload and short-circuit. They are also capable of making or interrupting electrical circuits. To perform the above mentioned functions, the circuit breaker must have an operating mechanism that can overcome a contact force of the order of 5N and open the electrical circuit in less than 3ms. Thereby, the size must not be much larger than a pocket watch.

To solve the problem, a system of levers with stops and latches is necessary. During the operation they could be deformed and the bearings (or rotating joints) have appreciable friction and the tolerances are large. Hence, for a realistic simulation of the motion of the system, elaborate pre- and post-processing and a high stability of the programme is required. To avoid too much time consumption at the end of the final and detailed construction, it was decided to begin with the preliminary simulation, simultaneously with the first draft of the construction. The idea was to follow the construction step by step through its developing phase and finally to arrive at the realistic model of the operating mechanism at the end of the construction. Thus the modelling time is distributed more or less equally over the whole period of development. The present paper describes these steps in the development of the mechanical operating mechanism of a circuit breaker.

2. The operating mechanism

The primary task which the operating mechanism has to perform is to move the moving contact from its closed to the open or tripped position and vice versa. Thereby, it works against the contact spring force. The mechanism is operated by a rotating knob (or grip). The contacts must close or open by itself as soon as the rotating angle of the knob exceeds a certain value. This is to prevent the welding of the contacts by intentional slow operation of the knob. The first draft of such a solution is represented in Fig. 1. This consists of :

9 levers
1 latch
1 rotating knob
3 springs.

3. The function

In the case of an overload or short circuit, the latch releases the supporting lever and thereby the mechanism opens the contacts. During opening or closing with the help of the rotating knob, the latch or the supporting lever do not move. A link_1 may rotate on the supporting lever. This link is connected to a knee-joint via another lever. This knee-joint moves a universal-jointed (cardan) lever in the Y-direction. The translatory movement of the cardan lever will be converted to a rotatory movement of the rocker with the help of a translatory and a rotatory joint - please also see the Fig. 2. In Fig. 2, the contact spring and the rocker spring are visible at the left and at the right hand side of the rocker respectively. In Fig. 3, the spring forces are represented, whereby the contact spring force will be zero as the contacts are closed. The rocker spring must be strong enough to keep the contacts in the position of rest. Referring to the Fig. 1, if the rotating knob is now turned, the slider will move via a driver along the housing parallel to the X-axis. The slider, with the help of a pin, will take with it the upper part of the U-shaped lever, so that a rotating moment is created at the lower part of the housing over a rotation-joint. A spring is stretched between the U-shaped lever and the link_1. This spring pulls the knee-joint towards the left as soon as a certain rotating angle is exceeded and thus closes or opens the contacts independent of further help from the operator.

4. The Problem

The Fig. 1 represents the operating mechanism in its earliest stage of development. The contact force, and with it the contact spring, is already defined. As the rocker spring must keep the contacts open, this can also be considered as known. By defining the positions of the mechanism and the contacts inside the breaker housing, the size of the rocker is also given. The rest of the geometry is practically unknown. With the arrangement as shown in Fig. 1, it is not possible to transmit sufficient force for the operation of the knee-joint with the help of a single spring on the U-lever. To reduce the mechanical stresses on the parts, the manufacturing costs and space requirement, it is to be considered whether an optimisation of the positions of the bearings is possible, so that the necessary force acting on the spring on the U-lever is so reduced that a single spring will be sufficient for the operation of the mechanism.

This problem was solved with the help of the new optimisation tool of ADAMS 8.2. The positions of the rotating joints (bearings) were chosen as the variable parameter. After consultation with the designer of the mechanism, the model for the variation of the positions of the bearings, represented by right-angles and lines, was created - see Fig. 4. The shifting of the positions of the bearings in the X and Y direction was defined as the variable for the optimisation. The characteristic of the spring on the U-lever was so defined that it can be realised with a single spring. A shifting of the positions of the rotating joints changes the rotating angle of the knob and also the contact travel. As the contact travel may not be too small and should be as large as possible, the maximum possible value of the contact travel was defined as optimisation criterion.
Hence, the optimisation task was defined as follows : find the maximum possible value of the contact travel for given spring forces by shifting the positions of the rotating joints.

The optimisation procedure was performed starting from various initial positions of the bearings to assure that it is an optimum over the whole possible area and not just a local one. The optimised positions of the rotating joints are represented in the Fig. 5. The spring forces on the U-lever before and after the optimisation is shown in the Fig. 6.

5. Summary

Due to its multiple functions, the mechanical operating mechanism of a circuit breaker is very complex and it is rather difficult to have a clear overview over all the various tasks it has to perform. For this reason, elaborate and time consuming simulation is necessary. Hence, simulation at each step parallel to the development process, beginning with the simplest construction to the final complex solution, is recommended. Only in this way it is possible to tackle this complex problem simultaneously during the development phase. The efficiency of this step-by-step method is presented in this paper with the help of an example of a development.

front model=Kardan7

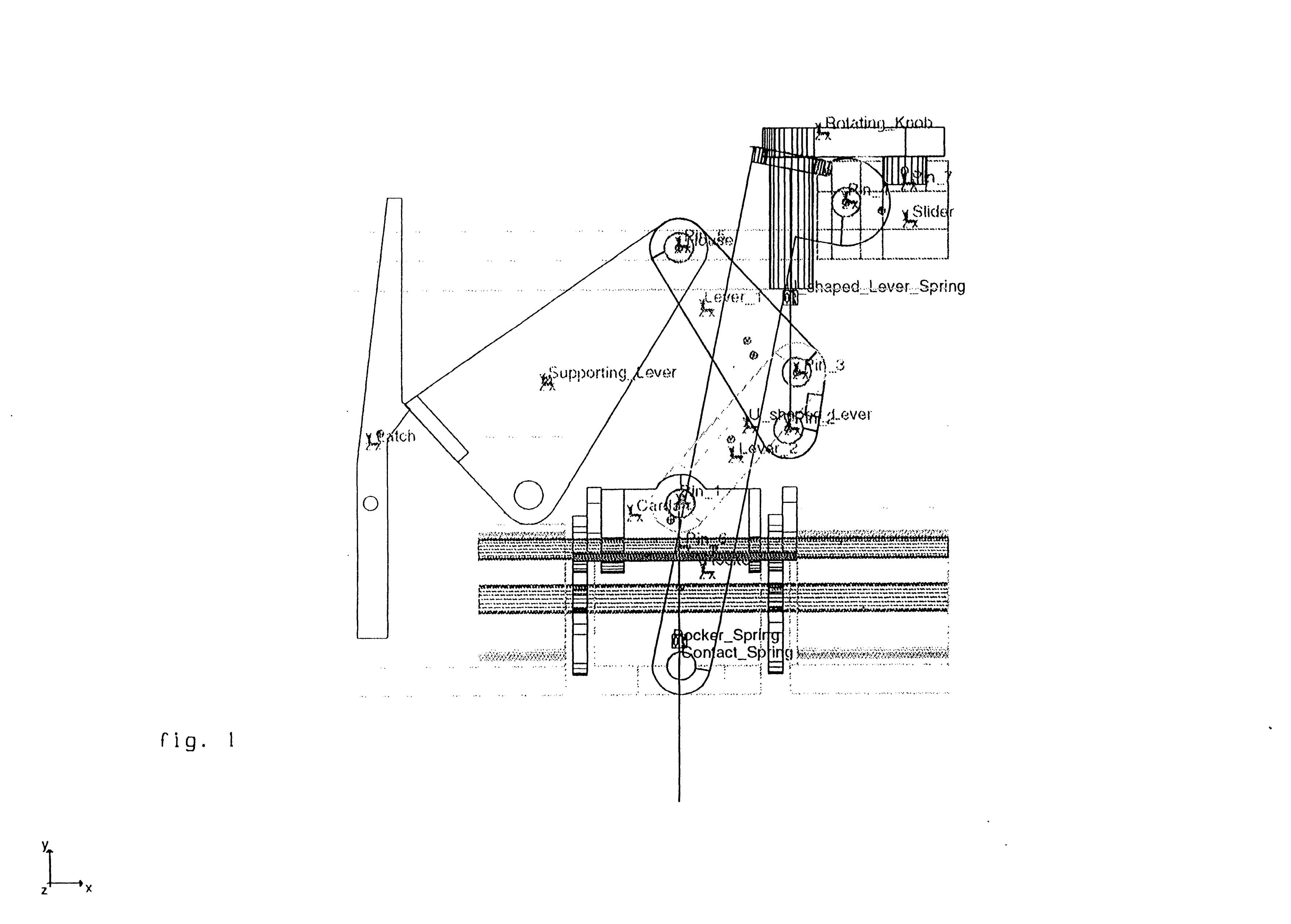


fig. 1

front model=Kardan7

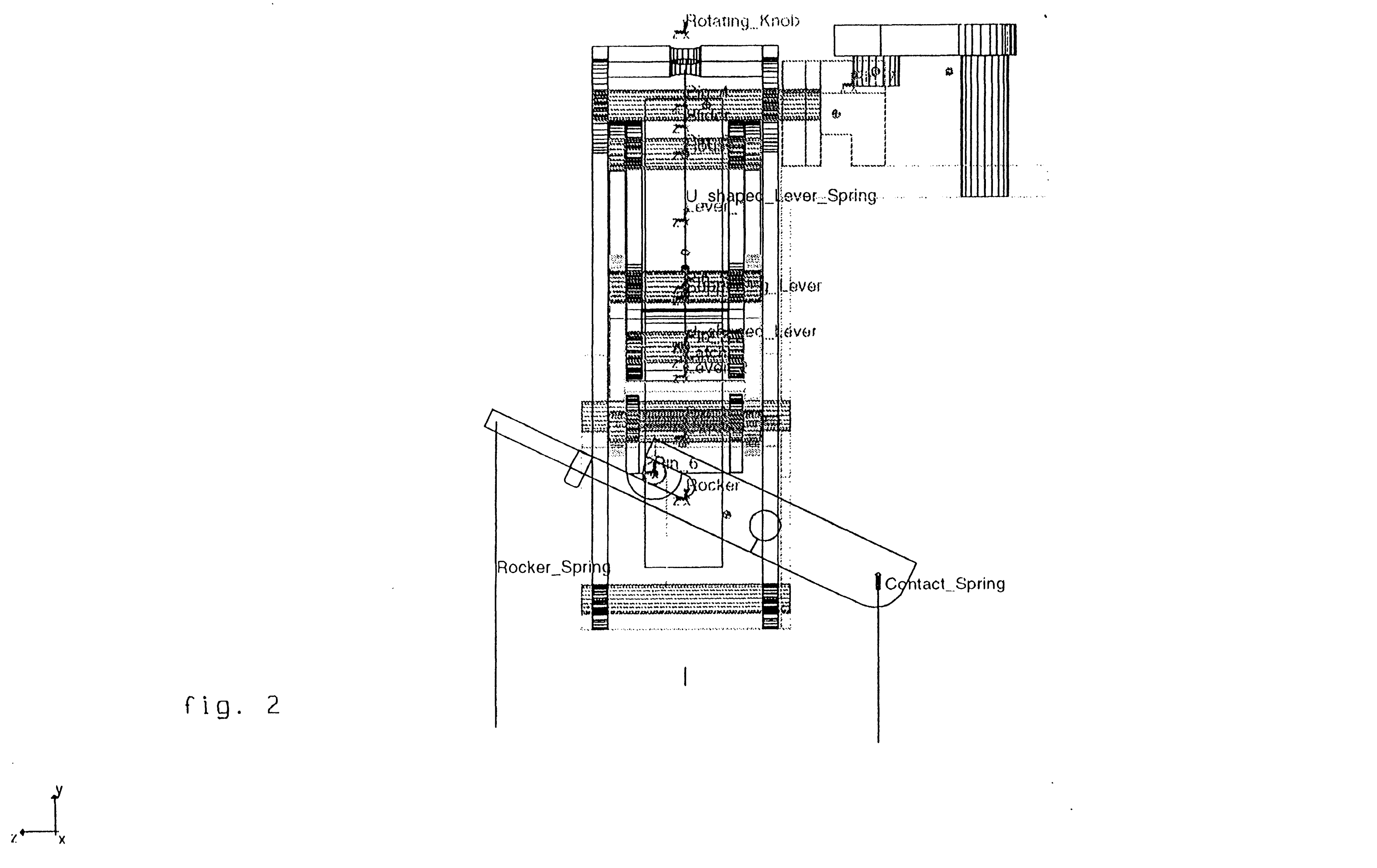
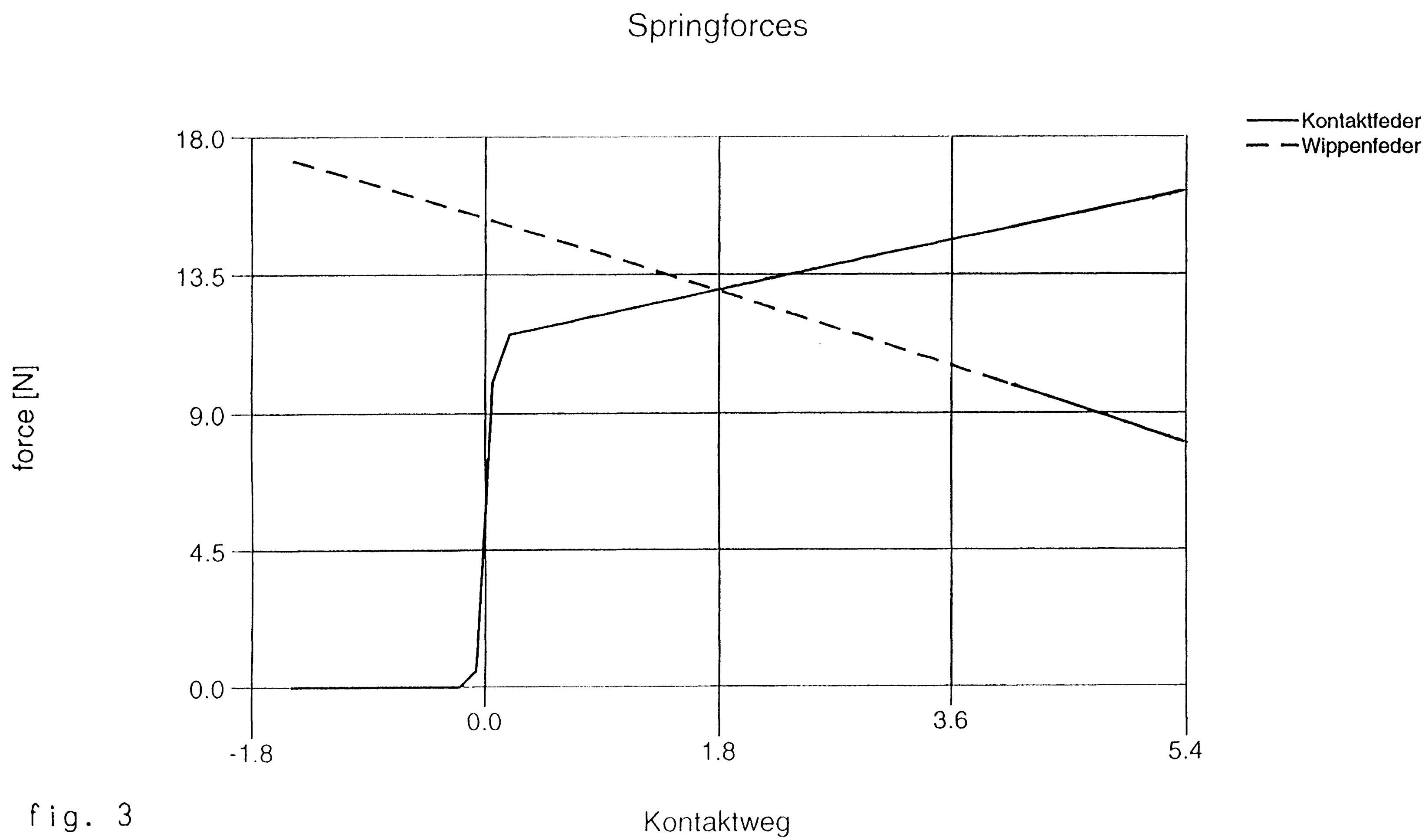


fig. 2



Springforces
Kontaktfeder
Wippenfeder
force [N]
18.0
13.5
9.0
4.5
0.0
-1.8
0.0
1.8
3.6
5.4
Kontaktweg

fig. 3

front model=Kardan7

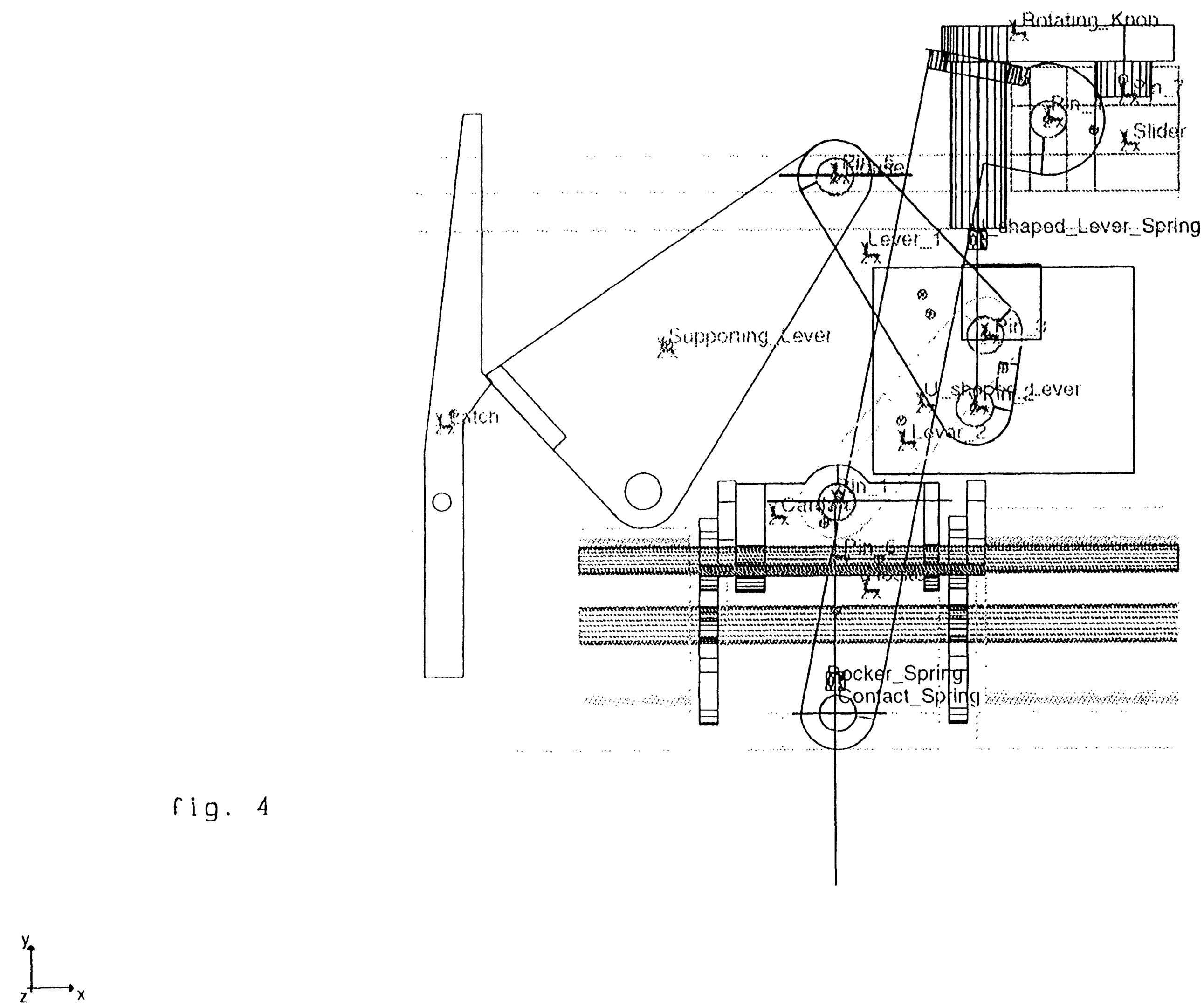


fig. 4

front model=Kardan7

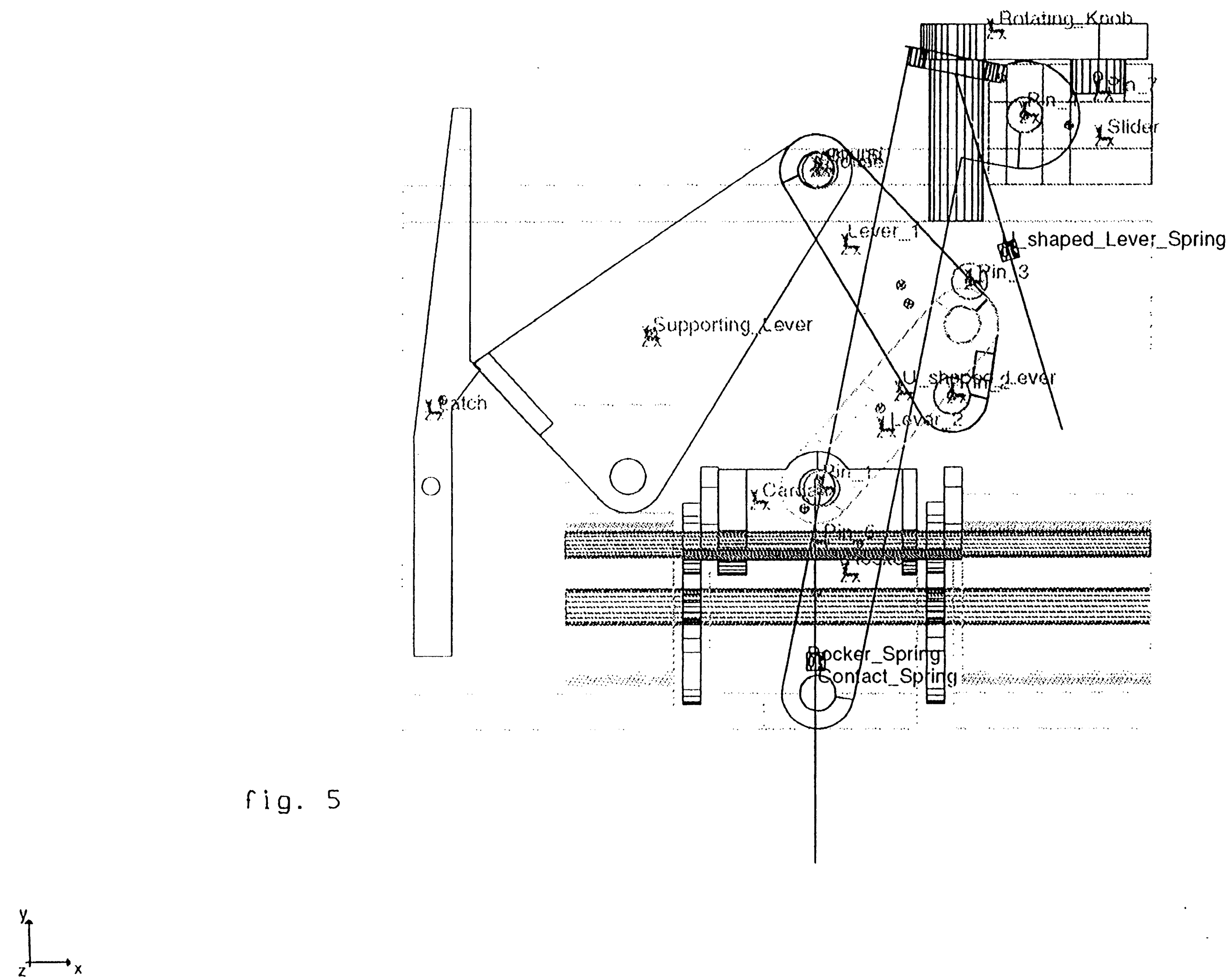


fig. 5

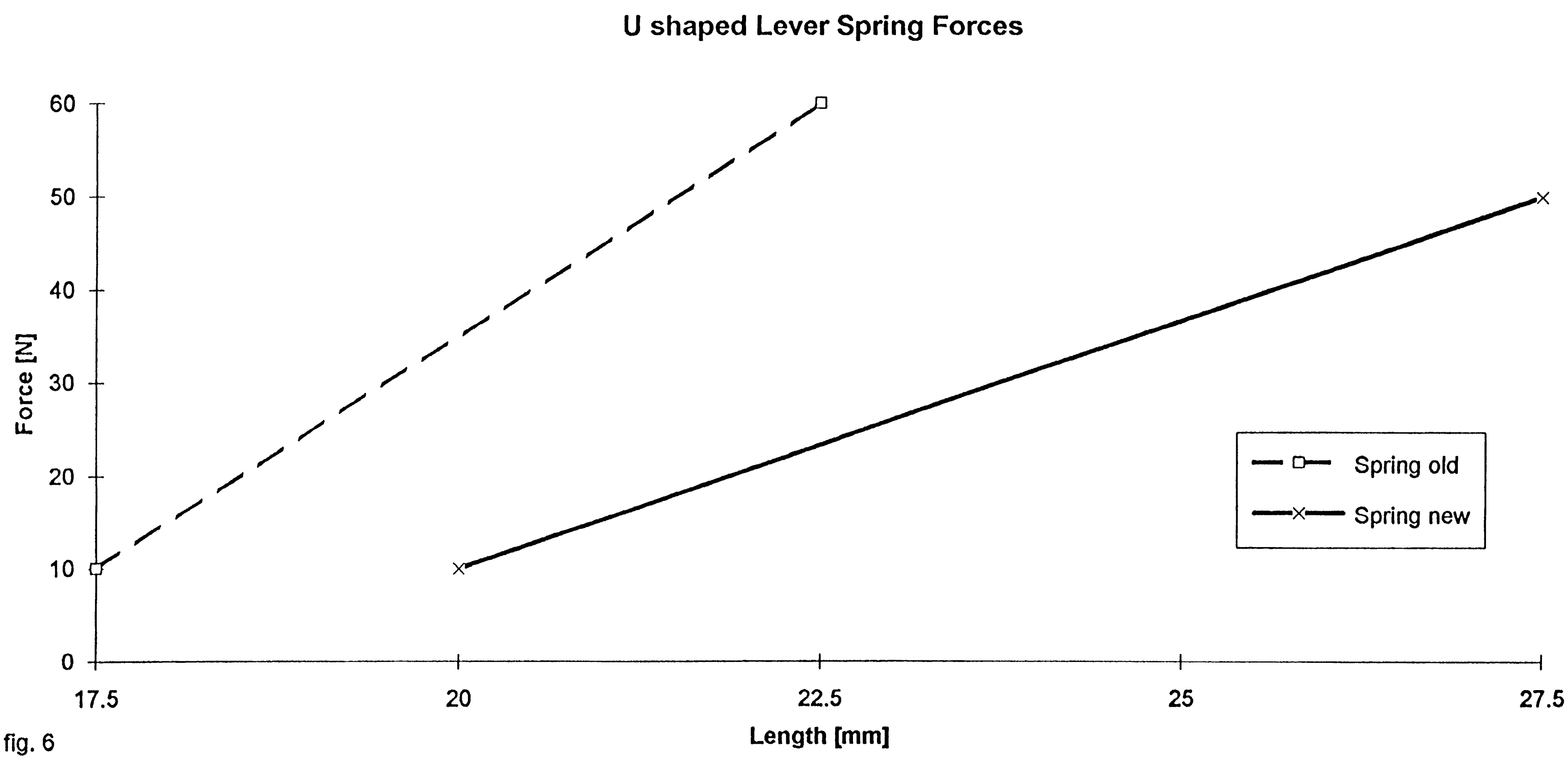

U shaped Lever Spring Forces
60
50
40
30
20
10
0
Force [N]
17.5
20
22.5
25
27.5
Length [mm]
Spring old
Spring new

fig. 6