FLEXIBILITY EFFECTS ON PRECISION FOR A STEELWIRE ELECTROWELDING MACHINE
"PAT.PEND."

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1 ABSTRACT

The aim of this work is to verify the positioning system of a steel rod which will be welded in a mesh electrowelding line.
This mechanism has to be easily adaptable to suit the various types of welded meshes while always maintaining a high productivity level.
The model was created and assembled using the I-DEAS CAD platform. The kinematic analysis to eliminate interference between parts, the synchronisation of the movements and the preliminary evaluation of the loads and torque forces were also studied using this platform.
A flexible model of a critical component, with respect to the positioning allowances requested by the machine was generated using the I-DEAS FEA module. The work was then developed using the ADAMS package analysing the modal and dynamic response.
The results of the ADAMS simulations were then reimported into the I-DEAS platform to correctly determine the stresses and strains in the component when under load.
The combined use of I-DEAS/ADAMS programmes has revealed to be a powerful instrument to design high performance equipment and, in particular, the evaluation of the structural deformations and their effect on the system operation, already during the initial design stage, lead to the solution of certain mechanical problems as well as the integration of the relative electronic control.

2 INTRODUCTION

The Pittini Group consists of independent procedures, each specialising in its own specific area, all leaders on the European markets and all benefiting from the synergies that Group membership brings. The working cycle is organised vertically and covers both steel production (electric arc process and hot rolling) and cold working and thermal welding.
IMPIANTI INDUSTRIALI S.p.A. is the engineering department that carries out all the Pittini Group design, technology and manufacturing of equipment for drawing, cold rolling and electrowelding of steel wire.
Impianti Industriali also supplies equipment suitable for the formation of new individual production lines, or additional components for the completion and upgrading of existing lines.

3 PRESENTED EXAMPLE

The machine shown in fig.1 belongs to an automated line for the production of electrowelded mesh. Its specific function is to position a section of cut-to-length cross wire in perfect contact with the longitudinal wires on the welding electrodes and hold it until the welding process is completed.

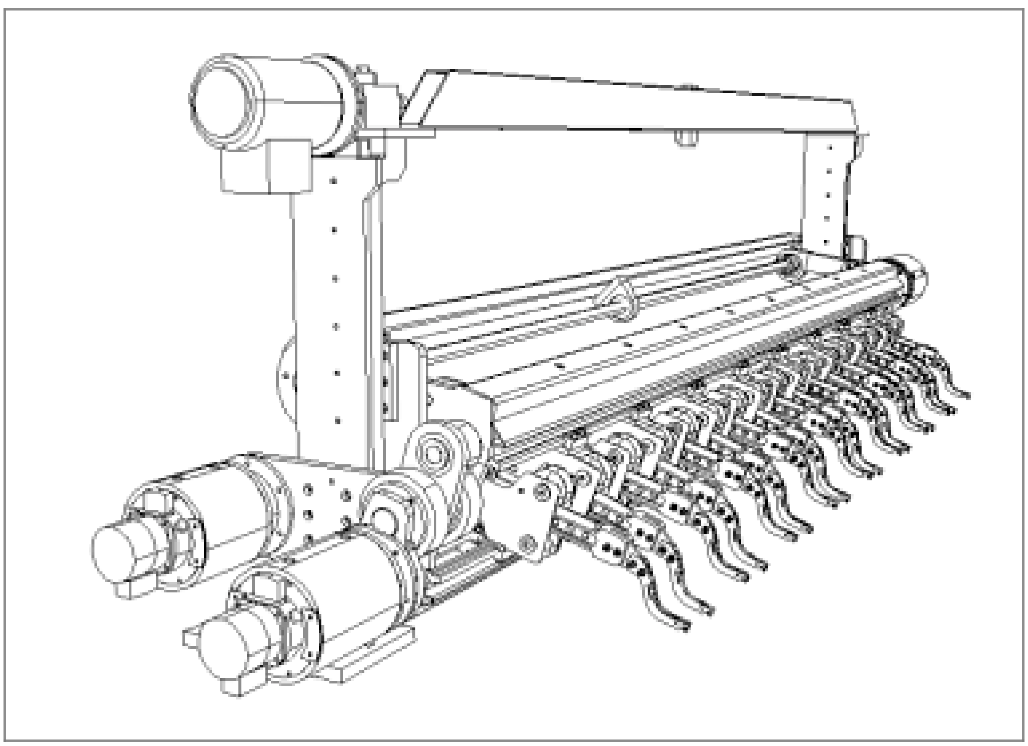

Fig.1 Machine assembly

The machine consists of a top unit and a bottom unit, having the same function; each unit has a set of clamps mounted that thanks to their magnetic ends hold and position the cross wire; a section plane of the bottom unit is shown in fig.2.

The overall motion is the result of two actions:

- Forward/reverse movement of the clamps, controlled by an hexagonal shaft on which the forks are mounted.
- Lifting/lowering movement of the clamps, controlled by a control camshaft.

Varying these two movements in excursion and phase it is possible to obtain the desired trajectory and modify it as necessary.
For this purpose, each unit is formed from two independently driven mechanisms based on the four-bar linkage system.
The two units are mounted one over the other so that the rotation centres are coaxial, and are co-ordinated in such a way that the dead times of one unit are covered by the other unit.

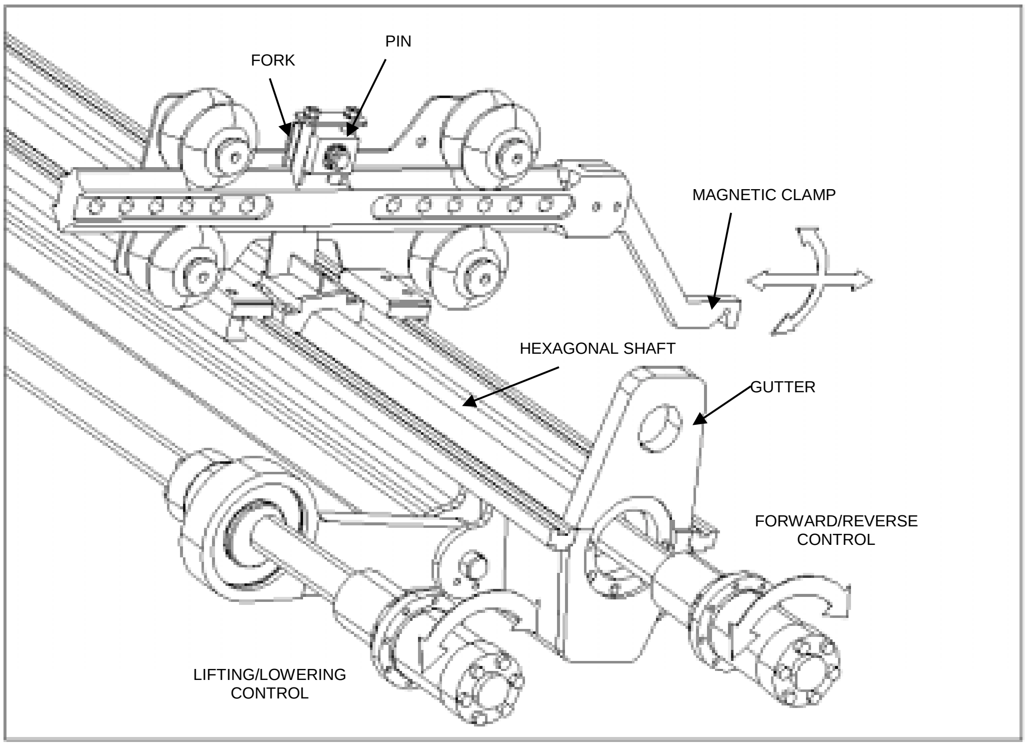

Fig.2 Diagram of the mechanisms

4 PROBLEM TO SOLVE

The machine being developed has the following characteristics:

- High working speed: 120-150 operations per minute.
- High flexibility: rapid set-up allowing different types of products to be manufactured varying both the wire diameter and mesh pitch.
- Synchronisation of the movements obtained by interpolation of the driven axles.
- High working loads.

Several critical points concerning the design emerge from the above characteristics:

- Geometric and operational parameters of the system.
- Correct evaluation of the loads and torque forces involved.
- Structural resistance.
- Dynamics of the overall mechanical system.
- Synchronisation of movements.

This article will focus on an important aspect of the design:

- The effect of deformation on the positioning of the clamps.

5 I-DEAS+MECHANISM DESIGN

The design process at Impianti Industriali follows the characteristic development for special machines, where critical factors are:

- Innovative design
- Performances
- Production costs
- Reliability

These objectives are often penalised by the conditions imposed by market needs, forcing the company to manufacture the final machine in a short period of time without creating a prototype.

As a consequence, the possibility of simulating and testing the machine operation using a “virtual prototype” has a strategic importance in reducing production costs and delivery times.

5.1 CREATING THE MODEL

In the case being studied, the design was carried out using the SDRC/I-DEAS software, starting from several 2D tables developed before the new system was acquired.

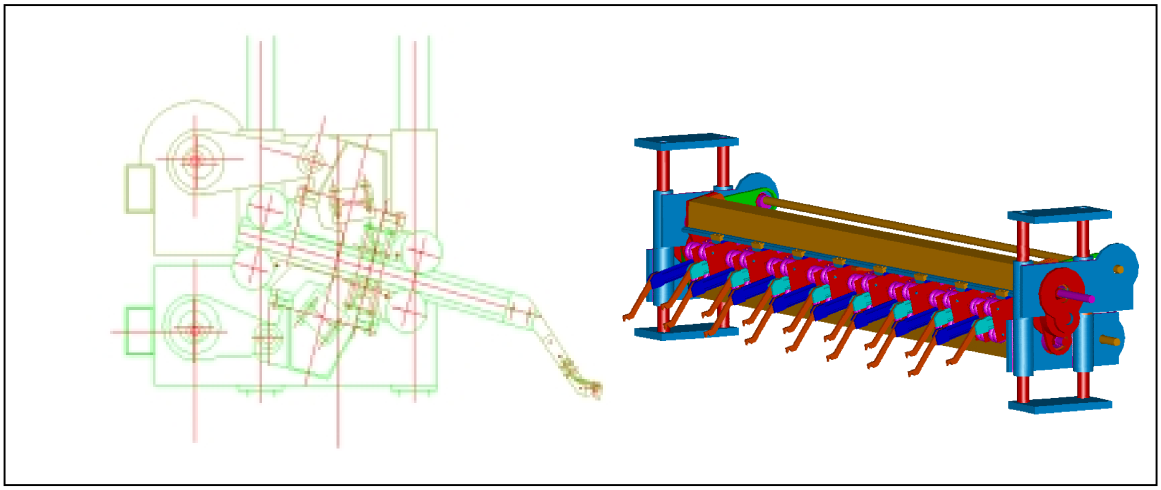

Fig 3 Conversion from 2D table to solid model

The parts were modelled from the two-dimensional geometry, the various features being added progressively, gradually improving the model in the course of the development of the design activity from the functional analysis to the final drafting detailing of the components.
A multilevel hierarchy based on the similarity of the units (though allowing for the kinematics of the system) was created to handle the various components of the assembly.
After completing the modelling stage, the general assembly consisted of 1146 entities including subassemblies and single parts; at the end of the designing stage the number increased to 2865 entities, including nuts and bolts.

The advantages of CAD 3D design at this stage of the project are the following:

- Generation of bills of material (BOMs), with the possibility of creating both the production BOM and the design BOM starting from the elements themselves (even though other software allow the design to be carried out by elements, IDEAS "compel" you to do so).
- Automatic calculation of masses.
- Analysis of interferences.

However, this methodology requires more work on the part of the designer, as the choice of the parameters and the constraints, two basic factors when large dimension assemblies are to be handled, deeply affects the processing times and the possibility of carrying out later changes.

5.2 KINEMATIC AND DYNAMIC ANALYSIS OF RIGID BODIES

The movement was initially displayed directly in the ASSEMBLY module. Having the possibility of "animate" a functional parameter, e.g. a crank angle, we could directly analyse some interesting design configurations as the working range boundaries and look for any interference.
The actual kinematic analysis was carried out with the MECHANISM module. At this stage it was important to focus on the following problems:

- The reorganization of the hierarchy, for the creation of the rigid bodies constituting the elements of the mechanism.
- The choice of the joints, which depends on the degrees of freedom (DOF) necessary for the mechanism, bearing in mind that, as the mechanics of rigid bodies does not allow all the mechanical constraints to be modelled without overconstraining the system, it is not possible to calculate all the constraint reactions.
- Identification of the ground
- Imposition of the motions on the residual degrees of freedom.
- Definition of external loads and friction.

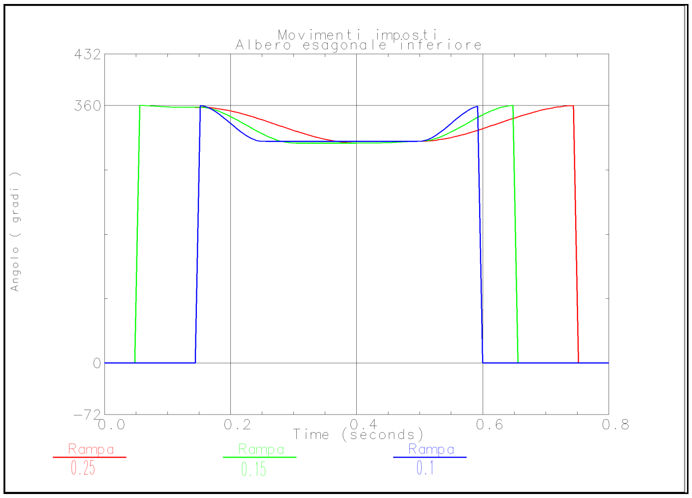

Fig.4 Example of applied motions

The simulation was carried out using an internal kinematic solver. Fig.4 shows an example of step type angular motions imposed to one of the motors, taking into consideration three different working cycles (ramps from 0.25s, 015s, 0.1s). After the calculation the following results were obtained:

- A number of configurations of the mechanism, which depended on the simulation time and the preset time step.
- A state vector with displacements, speed and accelerations, both linear and angular, of all the moving parts.
- A state vector with the constraint reactions and the torques/forces necessary for the movement.

In the post processing stage, we traced the torque curves for the four motors (one of which is shown in fig.5) and the reactions on the couplings.

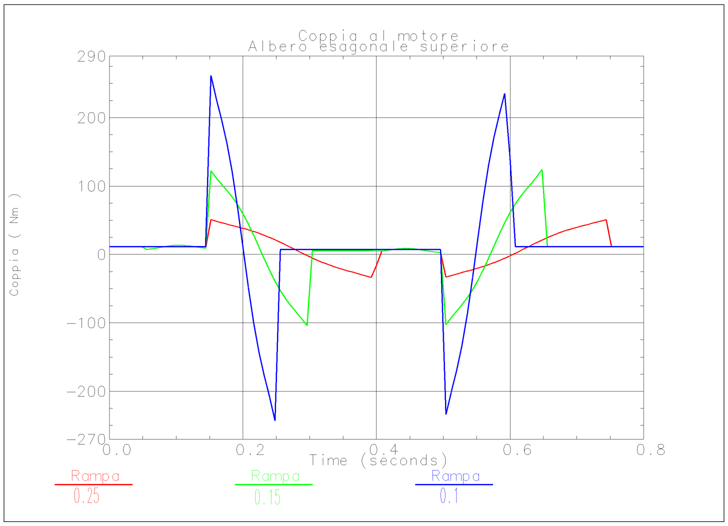

Fig.5 Torque necessary for three working cycles

Fig.6 Comparison between the torques on rotation cam shafts

From the examination of the curves of the torque applied to the rotation cam shafts (fig.6), it was immediately clear that in the first version of the machine the torque required to drive the bottom shaft was approximately three times greater than that for the top shaft.
Consequently the shape parameters of the cam mechanism of the bottom unit were optimised in order to reduce the torque peak to that of the top unit.

This product development cycle is greatly facilitated by the opportunity of working in a single design environment, where the parts can be modified while maintaining their rapport, and the system reanalysed any time it is necessary.

5.3 LINEAR STATIC STRUCTURAL ANAYSIS

The SIMULATION/FEA module was used to carry out the finite element analyses on some critical components indicated below, to determine the stresses and strains and ensure the correct structural dimensioning of the components:

- Fork: deformation problems leading to seizing of the guides
- Gutter: inaccurate positioning of the clamps
- Hexagonal shaft: synchronisation problems.
- Structure: structural resistance and rigidity.

The static linear analysis is based on the dynamic balance of external and inertial forces in accordance with D'Alambert's principle. At this stage, the studied parts were separated from the rest of the structure and an FEM model was created for each of them. As far as the gutter was concerned, the modelling required:

- A shell type mesh for the main body, made from 3mm thick bent sheet plate.
- A brick type mesh for the two sides, for the longitudinal profiles and the couplings.
- Some FE based boundary conditions to recreate the supporting pivots using spherical joints in the assembly points with the supporting structure and relevant connecting rods. The presence of the saddles was reproduced by connecting all the nodes in the locking bracket area, to a single node placed in the centre of gravity of each saddle, using rigid elements.
- Some loads with angular acceleration peak values and some internal forces between fork and pin applied in the barycenter nodes, previously obtained by the Post Processor of MECHANISM module in the most critical cycle.

Figs.7 and 8 respectively, show the stresses and strains (highly amplified) on the gutter:

Fig.7 FEM results: Von Mises stress

Fig.8 FEM results: Deformations

The dynamic characteristics of the gutter were analysed. For this purpose I-DEAS/FEA has an algorithm which allows the mode shapes to be determined.
The model derives from the one described above with the addition of lumped-mass elements to simulate the inertial properties of the saddles and the solution for the calculation of the first 10 main modes was laid down (fig.9).

Fig.9 1^{ST} mode displacements

The result was a first bending mode on the horizontal plane with frequency of 40Hz. The result prompted the stiffening of the structure with two longitudinal members having the function of increasing the bending mode frequency and distance it from that of the external force.

6 SIMULATION WITH ADAMS/FLEX

ADAMS/FLEX is an add-on module of ADAMS/VIEW, which permits dynamic analyses on flexible bodies.
The flexible component being examined is the gutter, as its bending and torsional deformation, even if small, can produce undesired movements from the required position of the clamps. The software uses the Assumed Modes Method, by which the actual deformations are broken down into a linear combination of mode shapes.

The input required by ADAM/FLEX is the Modal Neutral file of the flexible component to be inserted in the mechanism. This *.mnf file is generated in I-DEAS and later exported to ADAMS. In our example, the gutter was not replaced within the multi-body model of the entire charger but, in this case was separated from the other parts and was motioned independently. The analysis was carried out as follows:

- For the external constraint, the boundary areas including the heads and the couplings with the connecting rods, were taken to be as rigid.
- In the same way as for the above FEM analysis, the saddles were introduced as rigid bodies, but in this case an equivalent lumped-mass was applied in the barycenter node besides the constraint reactions (fig.10).
- The clamp holders were placed in the most advanced position, that is the worst condition both for load eccentricity and amplitude of displacements.
- The motion relevant to the most critical cycle was applied on the gutter rotation pin in accordance with the law obtained from the above kinematic analysis.
- To detect the positioning errors of each clamp, a measure of the distance as a function of time was created between a marker placed on the point of the flexible system, and a marker placed on the geometric coordinates which it would take if the system were rigid.
- After having launched a simulation of 1s in 50 steps, the displacement time law of all the clamps could be displayed with the post processor. Figure 11 shows the difference expected between the side and central clamps of the structure.

Fig.10 ADAM/FLEX model

Fig.11 Positioning error caused by the gutter flexibility

7 STRESS RECOVERY IN I-DEAS

ADAMS/VIEW can only calculate the time laws of the deformation of the structure in modal coordinates; in this case it is not possible to calculate the stresses.
Therefore, it is necessary to go back to I-DEAS to display the dynamic deformations in cartesian coordinates and the dynamic stresses (fig.12); furthermore an Event Evaluation File is created to carry out the analysis of the fatigue strength.

Fig.12 Real displacements under dynamic load

8 CONCLUSIONS

The use of the combination of the software packages I-DEAS+ADAMS proved to be a powerful instrument during the development of the design activity. Thanks to a more accurate estimation of the forces involved, it is possible to make a better choice of direct drive brushless servo motors, which are expensive and, due to their long delivery times, must be chosen beforehand.

In the future, we plan a greater integration with the electronic development control department for the simulation and optimisation of the feedback parameters of drives.