EUREKA PROJECT E!3188- FACTORY MSRPS

1. General description

Project	E! 3188- FACTORY MSRPS	**Status**	Announced- 18-JUN-2004
Title	**Mechatronic Systems For The Working Motions Of Machines**		
Class	Sub-Umbrella	**Technological area**	Robotics-Production automation
Start date	01-APR-2004	**End date**	01-JAN-2007
Duration	33months	**Total cost**	1.12Meuro
Partner sought	Yes		
Summary	Enhancing The Productivity, Quality, Variability And The Flexible Automation Of Manufacture By Means Of Mechatronic Methods.		

Budget and duration

Phase	Budget(Meuro)	Duration (Months)
Definition phase	0.74	21
Implementation phase	0.38	12
Total	**1.12**	**33**

Member contribution

Member	Contribution	Position	Since
Czech Republic	**67.00%**	**Contact Member**	**23-SEP-2003**
Germany	32.00%	Participating Member	18-JUN-2004
Slovak Republic	1.00%	Interested	23-SEP-2003

Participants

Company	Country	Type	Role
Vyzkumny Ustav Textilnich Stroju Liberec A.S.	**Czech Republic**	**SME**	**Main**
Sitec Industrietechnologie Gmbh	Germany	SME	Partner
Als - Anlagetechnik Und Sondermaschinen Gmbh	Germany	SME	Partner
Spinea S.R.O.	Slovak Republic	SME	Interested

2. Project outline

Project description

The project's objectives focus on two main areas:
AREA OF THE DESIGN OF MECHANISMS:
A tremendous boom in computer technologies during the last decades was followed very successfully by developments in machine building as well as electrical and electronic engineering. These branches, however, are very different because of their theoretical complexity and higher requirements on information processing. Nevertheless, there is a growing demand for productivity, quality, variability and flexible automation of manufacturing in technical practice. As a consequence, there is a demand for a higher performance of machines (working periods, revolutions), perfect acceptance of position functions of working links (dynamics of function-generating mechanisms with flexible links), multi-purposefulness in a small-lot manufacture (possibility of an economic advantageous change of motion functions) and design modularity of machines (flexible automation).
These production requirements can be satisfied by a synergic effect of the three above-mentioned branches in the solution of optimisation of motion functions that are realized by kinematic excitation. This kinematic excitation is derived from mechanical, electronic or combined cam mechanisms. The mechanisms are not replaced by each other, but mutual possibilities of individual alternatives are used.
The aim is to develop qualitatively new types of drives that should meet in an optimum way technological demands on mechanisms of working machines and influence notably the above-mentioned problems as well.
Phase 1.1 - Non-periodical displacement laws of cams
Non-periodical displacement laws are the functions transforming the uniform rotary motion to the non-uniform rotary motion with the rest intervals (carried out by indexing mechanisms) or without the rest intervals (carried out by out-of-roundness wheels or by indexing mechanisms without the rest position). These non-periodical displacement laws are carried out by various cam mechanisms with radial, axial or globoidal cams. The production of radial cams is most efficient from an economical point of view. We will therefore follow these mechanisms of conventional and unconventional design as well.
In this phase, suitable displacement laws will be selected, their theoretical as well as mathematical description and the formation of programmes that realize these displacement laws with numerical outputs in a form suitable for a later processing in such a way that analysis and synthesis of compound cam mechanisms will be calculated. Furthermore, the use of individual displacement laws will be defined.
As every displacement law excites kinematically the dynamic system of a cam mechanism and/or a compound cam mechanism respectively, it is necessary to deal with dynamic models of these mechanisms. By dynamic model we mean both a software (computer) model and a real one (stand) in which discrete masses, compliance and damping are simulated. Both models will respect flexible constraints in the output (driven) and the input (driving) part of the cam mechanism. The software dynamic model can be solved in two ways:
- Description of the discrete model of a cam mechanism by means of motion equations. The dynamic model has three degrees of freedom and will respect the driven mass with constant angular velocity, the cam, the output link of the basic cam mechanism (in technical practice it is mostly a rocker lever of the cam with rotary motion) and finally the mass of the working link. The flexible constraints between masses are described by compliance and damping. The numerical solution will be programmed and the results will describe transient and residual vibration in the rest interval of the cam.
- Dynamic model created in a higher computing and constructive software, e.g. ADAMS, IDEAS.
Both models must show a satisfactory correspondence of transient and residual vibrations.
The stand of a dynamic cam mechanism will correspond with the discrete software model - described by motion equations - with a flexible constraint in the driven part of the mechanism. The kinematic excitation, the cam respectively, will be realized by an electronic cam (a numeric controlled servomotor) with a suitable reduction of revolutions. In this phase the dynamic model will be designed in two versions:
- Design of the output part with discrete masses where compliance and damping are realized.
- Design of a compound cam mechanism when a function-generating mechanism - the transmission ratio of which is not constant - is inserted between the cam and the working link. This model conception will be used for verifying the rightness of the programmed displacement law of the electronic cam (tasks of the cam synthesis), eventually for determination of displacement law corrections with respect to required motion of the output (working) link. The function-generating mechanism will be designed with the highest rigidity.
Another step in Phase 1.1. is the design of a pilot plant dynamic model of the cam operated indexing unit with an electronic cam. The model conception complies with outside dimensions of a selected size of the cam operated indexing unit with radial cams. Also the output shaft with indexing motion will be of a conventional design. Thus the basic difference consists of the realization of the exciting function, i.e. radial cams are replaced with an electronic cam. The model will be designed in such a way to be able to replace a

conventional cam operated indexing unit in a concrete working machine and to determine dynamic parameters of the actual working machine, as well as to test on the basis of these values the proper displacement laws. Together with preparation for the said works, it is necessary to create a methodology and procedures for programming the electronic cam, where the displacement law is a result of modelling programmes for displacement laws of cams or this displacement law is the result of the synthesis solution of the compound cam mechanism.
The aim of this strategy is to determine the most suitable displacement law using the electronic cam and then to manufacture a conventional cam and respectively conventional cam operated indexing unit with this displacement law, which is in many cases manifold cheaper in comparison with the application of the electronic cam. On the other hand, it is quite evident that from an efficiency point of view, it is disadvantageous to seek the proper displacement law by means of production of a certain number of conventional cams.
For the dynamic stands with electronic cams, there is an inevitable reduction in revolutions due to the following demands put on the device being used:
- as low as possible moment of inertia
- high rigidity
- minimal hysteresis (run without backlash)
(The run without backlash is necessary because the second-order derivative of the displacement law, i.e. acceleration, is of plus and minus values. It results in backlash elimination and inadmissible strokes in the mechanism)
- high extent of transmission ratios
- as small as possible floor space.
Phase 1.1 will also contain an evaluation methodology for conformity of measurements and calculations.
A very important theoretical and practical field is an accuracy evaluation of manufactured cam profiles. It is evident that if the most suitable displacement law is determined with the help of the electronic cam, then it is necessary to manufacture the cam as accurately as possible. As mentioned above, we will consider non-periodical displacement laws, which are realized by radial cams. These cams are always produced in a pair and they are put into indexing mechanism mutually in a mirrored way. From the technology and the assembly results, production errors must be analysed from the standpoint of their influence on the function and the lifetime of all mechanism links. This dimensional analysis must be productive enough that it is possible to measure and evaluate each radial cam pair and to achieve a high lifetime of the cam operated indexing unit. Thus the aim is a software, which evaluates the measured data of cam surfaces and simulates the deviations from the theoretical form. It determines inversion values in the mechanism being the criterion for end use of manufactured cams. In this phase an automated programme for data evaluation of measured radial cams will be created as well as a theoretical basis for inversion evaluation.
Phase 1.2 - Conventional indexing mechanisms with radial cams
The introductory study will evaluate advantages when radial cams are used in indexing mechanisms and their comparison with other cam types, respectively other cam mechanism designs.
The work in this phase will be targeted at the computing of cams and the indexing mechanism design whereas high speed and high lifetime is to be achieved. Therefore it is necessary to develop a single-purpose programme for the design and computing of these special radial-indexing cams. This software must contain a simulation of the mechanism motion including computations and visualisation of all-important parameters, such as pressure angles of individual carrousel rollers, etc.
The programme will also contain the computation of the so-called 'cam profile-take-off'. The cam contours will thus be corrected on those segments, where the roller starts to contact the cam and where the roller passes through the 'dead point', i.e. when the roller passes through the line connecting the axis of rotation of the cam and the axis of rotation of the carrousel. Computing this 'cam profile-take-off' results in the fact that the cam mechanism is a statically definite system at an arbitrary position of carrousel, i.e. in any position, the carrousel contacts the cams with two rollers only. Without the 'cam profile-take-off' are the fields, where three rollers get in contact, the mechanism is statically indeterminate system and it comes to increased loading and considerable life-time reduction.
The following specific design, technological and production problems are connected with the cam computation:
- The design being supported with the computation must achieve the optimal mechanism geometry at the given axis distance cam - carrousel and at the given non-periodical displacement law, i.e. roller diameters, the pitch diameter of the carrousel rollers and the maximum width of the working surface of the cam must be determined.
- Slide bearing of the rollers and a special coating of the roller pins.
- 'cam profile-take-off' by grinding and by electro-erosive machining.
In this phase, the programme for automated evaluation of measurement including inversion values will be terminated.
Finally, in Phase 2.1 the dynamic model will be manufactured (indexing unit) with an electronic cam corresponding to one size of the family of cam operated indexing units with radial cams. This model will be

installed in a concrete working machine and the dynamic parameters of the mechanical system of the machine will be determined by means of the said model.
Phase 1.3 - Unconventional indexing mechanisms with radial cams
This phase will contain a detailed analysis of the technical status in the field of indexing mechanisms with an emphasis on high speed, high performance of the working step and dynamic (stability) of the working motion and the rest interval.
A functional model of the cam indexing mechanism (indexing unit) based on the differential will be designed and manufactured, i.e. with two inputs and one output of the non-periodical working function, so with combination of two inputs - one of them is the constant angular velocity exciting the working force motion (step) by means of a conventional double cam and the other input is the non-periodical function derived from the electronic cam, which after superposition with the first input makes the transient and the rest interval of the output function and reduces transient and residual vibrations of the mechanism in the field of the transient and the rest output interval.
The price of the electronic cam depends markedly on its power. Arrangement with the differential allows a great deal of the power to be added by means of a conventional cam mechanism. Only a small part of the power, needed for the elimination of transient and residual vibrations of the output, will be delivered from the electronic cam.
There is a real assumption that this qualitatively new type of drive will be able to solve problems which are otherwise unsolvable when using either conventional or electronic indexing mechanisms separately. Above all, this concerns motions where the working step moves the mass with a high moment of inertia, on the condition that residual vibrations are as low as possible.
All the R&D activities foreseen in this field are unique both in the CZECH REPUBLIC and abroad.
AREA OF THE PRODUCTION TECHNOLOGY OF MECHANISMS:
The present situation in machine-building places high requirements on suppliers of machine components and devices. The supplier must ensure the whole operation chain from the basic product development through its design and adaptation according to concrete customer demands up to the final production and delivery, sometimes including assembly, so that the customer obtains not only a separate assembly but also a fully operating system.
The same applies in carrying out the motion functions of machines and devices containing many highly precise parts complicated in their form (e.g. cams).
Another reason is the increasing demands on performance parameters of such mechanisms.
Today, sufficiently optimized technologies for machining are available, but reserves seem to be in the final processing of individual components of drive mechanisms. This means in particular that heat treatment influences the loading capacity, operating lifetime and reliability of mechanisms a great deal. The present trend, also being demanded by customers, is the surface hardening.
The following technologies for surface hardening exist:
- Flame hardening, not used much today because it is too dependent on the subjective attitude. It has been used marginally on machine parts where the very accurate layer after hardening is unnecessary.
- Induction hardening is one of the most applied methods of surface hardening. The heating is carried out with eddy currents from the inductor. For a hardening 1 mm-1,5 mm deep, high frequency aggregates are used; for 2-3 mm depth or greater medium-frequency aggregates are used. Only one company, MARTENZIT S.R.O. PRAHA, deals with induction hardening in CZECH REPUBLIC. Other companies deal with single-purpose mostly high-frequency aggregates, e.g. in the automotive industry AUTO-SKODA company. Induction hardening is suitable for larger production lots.
There is often a demand for the hardening of large machine parts in small quantities. In this case, it is possible to use gradual hardening. Heating is carried out by a short loop with a controlled motion - not by the circumferential inductor. The machine parts are gradually heated and cooled on their surface. In practice, there are technologies that are commonly used for round parts. However for complicated forms it is necessary to develop a device to move the inductor. It can be done by means of a master template or an NC (Numerical Control) controlled axis can be added to the hardening machine. Such technologies are used e.g. in GERMANY, but in the CZECH REPUBLIC are not practically available.
- Laser hardening is another modern technology for surface heating. Great progress has been made in laser techniques in general in many fields of end use (machining, welding, cutting, etc.). A higher number of suitable and available laser sources make this technique efficient and profitable in practice.
There is much to be done yet in this technology, therefore the research and development in this field will continue. There is practically no experience with this technique in the CZECH REPUBLIC and only a little abroad. There are many constraints and demands, among them the requirement to have an own hardening device.
The laser application is more difficult because the laser beam is too narrow. When the machine parts of complicated forms are to be hardened, it must be ensured that the laser beam acts across the whole surface gradually. It is only possible when the laser head performs the three-dimensional motion. The higher requirements come when axial cams are to be hardened. Their working surfaces are three-dimensional and the laser head must move in four coordinates at least relative to the treated parts. Experience both in the

field of machine building and laser technology is needed.
The aim of this part of the project is to evaluate the suitability of individual surface hardening technologies. The most suitable technologies will be selected and the research and development will be carried out so that it is possible to use them for specific applications, including the design, production and testing of suitable devices.
The hardness measurement of the hardened layer is a separate though necessary part of the project solution. Until now, destructive as well as non-destructive methods have been used. The hardness, however, is measured at one point only. A complex non-destructive hardness measurement for the given application would be preferable. At present, discussions are underway on another partner joining the project (a German company) - a specialist in the given field.
Phase 2.1 Elaborating the solution concept
The tasks will be specified and made concrete in this phase. The assortment will be determined (size, quantity, etc.), potential alternative technologies for surface hardening will be proposed and assessed in terms of economic exigency and possible integration into the whole manufacturing technology as well.
Phase 2.2 - Realisation and testing of the selected alternative devices for surface hardening
Technological trials will be made on the heating types selected in Phase 2.1. At the same time, suitable components will be selected and a demonstrative device will be planned, designed and manufactured. It is impossible to say at this stage whether a universal device will sufficient or whether it will be necessary to develop and to manufacture two devices (induction - laser).
Phase 2.3 Testing and evaluation
The designed device will be put into operation in this phase, technological tests will be carried out and optimum operation parameters will be sought. Based on the results, the device as well as technology will be optimized.
Keywords: mechanism, mechatronics, heat treatment.

Technological development envisaged

As described above, the project aims to carry out research on non-periodical displacement laws and their realisation by mechanisms using the support of mechatronics. At the same time, the necessary activities will be carried to achieve the second aim of the project, i.e. developing a suitable technology for the manufacture of new designed mechanisms.
The project aims to enhance the productivity, quality, variability and the flexible automation of manufacture by means of mechatronic methods. These methods will be applied in motion functions (non-periodical displacement laws) of working links of production machines.
The aim is to develop qualitatively new drives that ensure, in an optimum way, technological demands on working motions of mechanisms of these production machines.
A further, equally important, aim is to develop a machine device with an appropriate heat treatment technology for parts complicated in their form, which are used as working links of production mechanisms. The application of gradual inductive hardening and laser hardening is expected.

Markets application and exploitation

The project outputs will have a large potential for future exploitation. It is possible to define at least 5 fields in which the results could be used:
- Cooperation in computation and design of mechatronic systems to realize the working motions of machines (VUTS, SPINEA)
- Production of these mechatronic systems to realize the working motions of machines (VUTS, SPINEA)
- Cooperation or respective design of machines and devices using these systems and their production (VUTS, ALS)
- Design and production of machines and devices for heat treatment of parts complicated in their form (SITEC, VUTS)
- Made-to-order realisation of the heat treatment of parts complicated in their form (SITEC).

The planned market exploitation is based on the business activities of the individual companies and their assessment of expected income. They also believe in real rate of return on invested means.
The main markets will be GERMANY and other E.U. countries, and by ALS company also markets in Asia and South America. VUTS and SPINEA expect to realize a certain volume of orders in the CZECH REPUBLIC as well as other E.U. candidate countries.

Project codes

BSI

NQ	mechanical systems
NQM/NQN	gear drives
NQM.Y	gear boxes (speed reducers)
PF	heat treatment

NACE

295	Manufacture of other special purpose machinery
292	Manufacture of other general purpose machinery

3. Main participant

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Organisation type	SME
Participant role	Main

Contribution to project

- Total project control, coordination of work procedure - Share in limitation of area and extent of development work - Proper implementation of determined stages of solution. PHASE 1.1 - Set of suitable displacement laws including programmes for computation of analysis and synthesis of compound cam mechanisms. - Dynamic models of cam mechanisms. - Design processing the testing stand containing the electronic cam. - Design processing the pilot plant dynamic model containing the electronic cam. - Methodology for programming the electronic cam for non-periodical functions. - Methodology for measuring and evaluating the conformity of measuring and computations on a dynamic model of the cam mechanism. - Measuring and evaluating the accuracy of radial cam profiles. PHASE 1.2 - Computing, technological and manufacturing processes targeted at the high speed and enhancement of the operating lifetime of the indexing mechanisms with radial cams. - Software for computation and simulation of these mechanisms including the computation of 'cam profile-take-off'. - Realisation of 'cam profile-take-off' by suitable production technologies. - Automated evaluation of the measurements of these cams including inversion values. - Production of a dynamic model with the electronic cam and its examination in a concrete task (in practice). PHASE 1.3 - Study as well as analysis of the technical status in the field of indexing mechanisms with radial cams based on the differential. PHASE 2.1 - Technical and economical analysis of practicable applications of individual technologies of the surface hardening. PHASE 2.2 - Results of technological tests. - Technical documentation. - Device to be demonstrated. PHASE 2.3 - Results of technological tests. - Optimised technology and determined operation parameters.

Expertise

The organisation was established in 1951. It targets R & D in textile techniques and technology. The firm is well known with a lot of word patents in the world of engineering. At present, VUTS is a join stock company that deals with research, development and design of machines and equipment for the manufacturing industry in the field of textile machines, packers, blue printing machines, polygraph machines and now also tool machines.

4. Partner

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Organisation type	SME
Participant role	Partner

Contribution to project

Participation in the following phases: PHASE 2.1 - Technical and economical analysis of practicable applications of individual technologies for surface hardening. PHASE 2.2 - Results of technological tests - Technical documentation - Device to be demonstrated. PHASE 2.3 - Results of technological tests - Optimised technology and determined operation parameters.

Expertise

The main activities of the company are the development, design and production of assembly devices, devices for laser machining, testing stands and devices for electro-chemical machining. Within the project, the company will cooperate in terms of developing a solution for heat treatment (surface hardening) first of all by means of laser. A device will be designed in which the heat treatment technology of parts complicated in their form will be developed and tested.

4. Partner

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Organisation type SME
Participant role Partner

Contribution to project

Participation in the following phases: PHASE 1.1 - Set of suitable displacement laws, including programmes for the analysis and synthesis of compound cam mechanisms. - Dynamic models of cam mechanisms. - Design processing of the testing stand containing the electronic cam. - Design processing of the pilot plant dynamic model containing the electronic cam. - Methodology for programming the electronic cam for non-periodical functions. - Methodology for measuring and evaluating the conformity of measuring and computations on a dynamic model of the cam mechanism. - Measuring and evaluating the accuracy of radial cam profiles. PHASE 1.2 - Computing, technological and manufacturing processes targeted at increasing the speed and enhancing the operating lifetime of the indexing mechanisms with radial cams. - Software for computation and simulation of these mechanisms including the computation of 'cam profile-take-off'. - Realisation of 'cam profile-take-off' by suitable production technologies. - Automated evaluation of the measurements of these cams including inversion values. - Production of a dynamic model with the electronic cam and its examination in a concrete task (in practice). PHASE 1.3 - Study as well as analysis of the technical status in the field of indexing mechanisms with radial cams based on the differential.

Expertise

The main activities of the company are the development, design and production of single-purpose (packaging) machines and mechanisms. Within the project, the company will cooperate in defining the tasks, looking for applications for the new developed mechanisms, verification of theoretical results and models and their comparison with the actual ones, and testing the new mechanisms.

4. Partner

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Organisation type SME
Participant role Interested

Contribution to project

Participation in the following phases: PHASE 1.1 - Set of suitable displacement laws, including programmes for the analysis and synthesis of compound cam mechanisms. - Dynamic models of cam mechanisms. - Design processing of the testing stand containing the electronic cam. - Design processing of the pilot plant dynamic model containing the electronic cam. - Methodology for programming the electronic cam for non-periodical functions. - Methodology for measuring and evaluating the conformity of measuring and computations on a dynamic model of the cam mechanism. - Measuring and evaluating the accuracy of radial cam profiles. PHASE 1.2 - Computing, technological and manufacturing processes targeted at increasing the speed and enhancing the operating lifetime of the indexing mechanisms with radial cams. - Software for computation and simulation of these mechanisms including the computation of 'cam profile-take-off'. - Realisation of 'cam profile-take-off' by suitable production technologies. - Automated evaluation of the measurements of these cams including inversion values. - Production of a dynamic model with the electronic cam and its examination in a concrete task (in practice). PHASE 1.3 - Study as well as analysis of the technical status in the field of indexing mechanisms with radial cams based on the differential.

Expertise

The main activities of the company are the research, development and production of high-precision reducers of the bearing reducers Twinspin (which are high- precision units based on a relatively new reduction mechanism) and a new design solution for the radial-and-axial output bearing. The units represent a relatively new generation of systems for the moment transmission. Within the project, the company will cooperate in looking for possibilities to use these reducers directly on the output shaft of the servomotors (electronic cams) based on additional research and development targeted at the specific end use.