“Completely flexible and reconfigurable fixturing of complex shaped workpieces with MRF””

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0 PUBLISHABLE EXECUTIVE SUMMARY

General description and objectives of the project

In the components manufacturing sectors it is considered by many that **fixturing** is the last **obstacle** to truly **flexible manufacturing operations**. In fact, fixturing frequently constitutes a costly and time-consuming **barrier** to meeting the challenge of shorter runs necessitated by more demanding consumers. Variety in choice of products is what consumers seek and what manufacturers have to provide.

When processing small batches of parts it is very common that a dedicated rigid fixture does not turn out to be economically feasible. In these cases the most widely used flexible fixture are **adjustable fixture** and **modular fixture**.

The European aerospace sector is characterized by a small number of very large firms and a very large number of SMEs. Most of these SMEs belong to the third tier and produce machined parts and prototypes. These SMEs **have important limitations for the application of adjustable or modular fixture to manufacturing of workpieces with complex curved surfaces or with multiple ribs and walls** which must be held during manufacturing operations. Therefore they design and manufacture customized fixture for each workpiece that obviously are technically very complex and labour intensive and/or too expensive.

Another important **problem** occurs during the material removal process in compliant (such as non-rigid “skin” type) workpieces or in those whose structure weakens while machining progresses. In these cases the workpiece or particular **weak zones of it are liable to deform and even break out**.

In recent years, the problems associated with conventional technology have invited research into novel, universal workholding techniques. **Ice clamps, fluidised beds and RFPE with melting materials are approaches to achieve such universal fixturing objective**, **but thermal deformations associated with temperature changes and lack of clamping force have confined them also to particular components, operations and/or materials** consolidating them as flexible and reconfigurable alternatives but definitively not universal ones.

This reflection, and previous knowledge and experience with rheological materials, has lead the **MAFFIX project** Consortium to **propose the development of a new type of universal fixture based on** ***magneto-rheological (MR) fluids***, ***a class of smart materials which drastically, fastly and reversibly change their consistency in a magnetic field***.

Contractors

RTD partners:

Industrial partners:

Results achieved during the project

MAFFIX consortia have designed, manufactured and validated technically and economically a **flexible and reconfigurable tooling suitable for long parts without reference faces based on MR fluids**. It is defined as flexible and reconfigurable as it can be easily adapted to different profile's lengths and sections and it is able to fix parts without reference faces as the MR fluid adapts to the outer shape of each profile. The MR tooling has allowed **reducing in one unit the number of different toolings** needed to manufacture the part under study.

Regarding its behaviour **under real machining efforts**, it can be concluded from the machining tests performed that the **MR fixture is able to support the cutting forces applied**.

From the **economical point of view**, the new MR fixture means a **great cost reduction** in the manufacturing of the final part because of mainly 2 reasons: i) the fact that **1 tooling less is needed** to manufacture the final part and ii) the **uploading time** has been **reduced from 80 min to 45 min**. Currently 4 uploading are needed and each of them takes around 20 min whilst using the new MR fixture, 3 uploading are needed and one of them only takes 5 min instead of 20 min.

Potential impact

MAFFIX is a CRAFT type project where SME partners obtain all the properties rights of the results reached. The SME proposers have two different profiles, fixture manufacturers and end-users, and the benefits that they will obtain for the project depending on their profile can be summarize as follows:

FIXTURE MANUFACTURERS

- According to market trends toward increasingly complex workpieces produced from reshaped or primary formed blanks and the fact that the percentage of blank material machined continues to fall, these workpieces introduce a unique set of clamping-related problems that cannot be solved with today's clamping systems.
- **Increment of their annual turnover** due to the **sales of an innovative flexible fixture** that will be reconfigurable and reusable for almost any component regardless of its shape, material and structural stiffness (including compliant thin wall and sheet like components).
- The flexibility of this fixture will offer the possibility to **compete in new application fields** such as aerospace, automotive sector or molds and die manufacturing sector. Consequently the fixture manufacturers will **access to new markets sectors or increase their competitiveness in sectors where they are already present**.

END-USERS

- Radical reduction of the total cost of final pieces up to 20%.
- Reduction of total manufacturing time and consequently of delivery time up to a 30%
- Increment of production rate due to **decrease of time needed for clamping / unclamping** the workpieces and due to the increased clamping strength and stability that is envisaged with the MR fixture and that will make possible the **introduction of higher cutting forces** improving the cycle times of the process.
- **Higher quality of finished part** than the one obtained with the fixturing systems and machining methods currently used
- **Capability of machining components currently manufactured by other alternative processes**: chemical milling ("skin" type slim components with very low stiffness), rapid-prototyping (parts wholly formed by complex curved surfaces).

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There is an official web site of MAFFIX project (http://maffix.fatronik.com) where all the information related to the project is included.

1 PROJECT OBJECTIVES AND MAJOR ACHIVEMENTS DURING THE REPORTING PERIOD

1.1 General project objectives

The **main objective** of the MAFFIX project is the development of a completely flexible, reconfigurable and reusable workholding system capable of locating, clamping and supporting firmly any type of component independently of its shape, material and structural stiffness while several machining operations or other manufacturing related operations are exerted on it. For achieving such objective a new type of fixture based on magnetorheological (MR) fluids will be developed.

The **scientific/technological objectives** to achieve in order to develop a fixture concept capable of being successfully introduced into Aerospace industry SMEs' shop floors are the following:

- High holding forces on the component
- Development of a MR fluid with properties according to the requirements of the fixture system
- Chemical stability of the fluid (not reacting with the workpiece)
- Phase-change property stability (avoiding sedimentation or thickening of the fluid)
- Uniform characteristics throughout all the material volume
- MR fluids with high sedimentation stability over time or "non-settling"
- Amenability of the MR fluid to being scaled to volume production (the process for making the fluid must be scalable and permit a low production cost)
- Good access of the cutting tool to the work areas
- Ease and fast operation times for loading and unloading the workpiece (auxiliary components/operations in the fixture apart from those included in the MR system reduced to the maximum)
- Simplicity of workholding setup and teardown in the machine table/pallet
- Capability to absorb and damp induced vibrations in the workpiece from the cutting process
- Capability to guarantee a definite location and orientation of the workpiece, being repeatable throughout the production run
- Compactness of the system including the magnetic circuits components
- The fluid should be easily recyclable (filtering will be important to remove contaminations such as chips)

The main **economic and industrial objectives** are as follows:

- Improve the competitiveness of the SMEs that will manufacture the flexible fixture with an innovative product. The system manufacturers will have its sales increased with a growing market available.
- Increase of the competitiveness of the SMEs that carry out the precision manufacturing and/or prototyping production. The increase of market outside Europe could be really significant, due to the reduction of cost and increase of productivity.
- Capital investment in aerospace part machining systems potentially could be reduced by millions of euros annually.
- A radical reduction of the total cost of final pieces, because nowadays the design and manufacture of customized fixture for pieces increase the pure manufacturing cost of final parts up to 5 or 6 times.
- Lead-time necessary for part changeover will be drastically reduced along with the overall cost of part machining. The productivity will be increased, though. Actually, in prototype manufacturing for the aerospace industry, about 50% of the spent time is due to special fixture design and manufacturing. The new fixture system will allow reducing this percentage in a drastic way.
- Quality of finished part higher. When the fixture system is not good enough, the quality of the finished part is compromised. With this new flexible fixture system the quality of the finished part will be optimized.
- Productivity increase. Currently, when the fixture system cannot satisfy the required fixture quality, the machining speed must be decreased in order to achieve a sufficient quality. This speed decrease means a productivity decrease. The new flexible fixture system will avoid these speed decreases in machining, and thus achieve a higher productivity.

The **social objectives** are:

- Elimination of labour and tedious fixture system design based on past experience and “trial-and-error”, which may be stressful for the operator.
- Increase of customer satisfaction, due to an improvement of the products quality by optimizing the manufacturing elements.
- To develop dissemination at European level, both to other industrial manufacturers and final users, taking advantage of the international market of the involved companies.
- Creation of new jobs by the increase of the competitiveness of European companies through the introduction of more efficient production processes.

The **environmental objectives** are:

- Reduction of wastes due to workpieces deforming too much or breaking down because of machining processes with inadequate fixture systems.

- Eventually, reduction of the highly polluting chemical milling. For removing material from non-rigid “skin” type workpieces a process used in several sectors is chemical milling, where the workpiece is completely sunk into a water tank with chemical re-agents that etch the material in those zones non protected by masks. This is a productive process, but definitively non-sustainable. The high amounts of water needed and the chemical reagents used, highly polluting, advise its substitution by other type of manufacturing processes less harmful to the environment.

Time to market: this project will deliver a prototype of the flexible fixture system that is expected to be fully commercialised within one year after project completion. During this period the system will require further work involving comprehensive field-testing and production engineering of the system to satisfy cost, performance and quality criteria in full-scale production of the device. The 3 fixture manufacturers involved in the MAFFIX project will take the responsibility to market the system all over Europe, increasing European aerospace SMEs’ competitiveness.

1.2 Objectives for the reporting period M0-M26

The objectives of the reporting period (whole project) are to develop and finish the 3 phases defined in the proposal:

- **Phase 1**- WP1: Consortium end-user requirements definition and compilation for the MR fixture
- **Phase 2**- WPs 2&3: development and construction of the novel MR fixture and the special MR fluid including all the necessary research and design stages
- **Phase 3**- WPs 4&5: testing, final improvements and modifications, evaluation and validation of the technology for representative applications under real industrial conditions

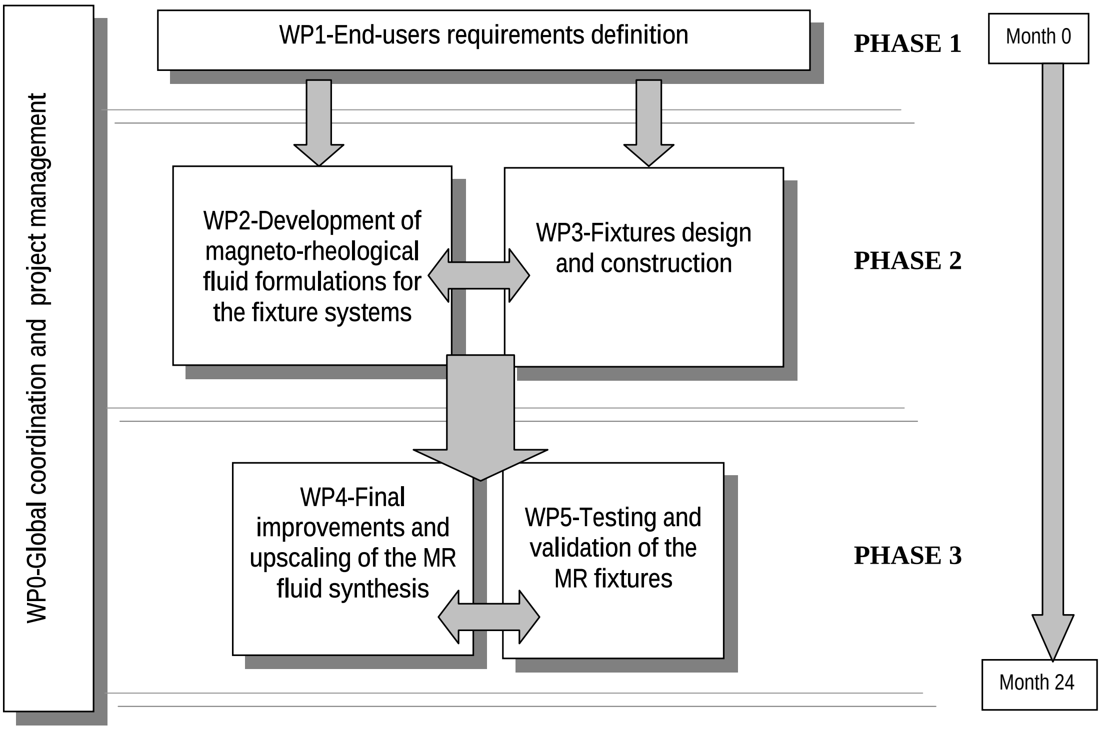


Figure 1 .PERT diagram of MAFFIX project

The activities of the project will start with a first workpackage where the current components, their associated machining processes and fixture being used by the end-user partners of the Consortium will be analysed in order to identify the more suitable working scenarios for introducing MR fluid based fixture and thus for focusing the development of the fixture of the project. As a result of this analysis a limited number of the workholding processes (two or three at the most) will be identified as the most suitable ones for being tackled by MR fixture. This identification of candidate workholding processes will involve an introductory learning phase where (1) the RTD partners become familiar with fixturing technology and the technical requirements, and (2) the fixture manufacturers and end-users become familiar with MR fluid technology and its possibilities. A solid understanding of the respective technologies will allow the formulation of innovative, but realistic goals for the project development. After this the expected needs to be met and problems to be solved by **MR fixture** with regard to existing fixturing methods will be clearly stated by the end-user partners. These **requirements** will be stated and defined as broadly as possible, but specifically enough to define the scope of the fixture to be designed.

This way the **next phase of the project**, comprised of WPs 2 and 3, will be provided with the necessary data to develop the main components of the fixture. In **WP2** special MR **fluid formulations** which are appropriate for the requirements of the fixture processes **will be synthesized**. The MR fluids will be developed in consecutive steps. Starting with a MR fluid with already known composition the properties will be improved by the variation of the components (magnetic particles, carrier liquid and chemical additives). The material properties most relevant for the fixture will be determined by rheological investigations as well as by basic experiments. As the profile of the MR material properties has to be adapted to the workholding methods and to the design of the fixture systems permanent information input coming from WP3 will be needed in WP2.

In fact, in **WP3** the **design of the electro-magnetic and structural parts of the fixture will be developed** according to the end-user requirements derived from WP1 and considering both technical and economical criteria. In the first place the partners will outline several fixture system concept(s) and their associated operational procedures and machining process implications for fulfilling the process requirements coming from WP1. Then the best fixture options for following with their development along the project will be chosen basing the decision on technical and/or industrial criteria, and on a cost/benefit analysis of the different tooling options. This cost analysis will also be needed, together with the budget limitations, for determining the final number of fixture to be built in the project (it is expected that at least two different fixture for two different processes will be built). These systems will finally be designed and manufactured during this workpackage. Particular possible requirements that the MR fluid may impose to the fixture structure will be obtained as the work in WP2 progresses. This WP3 will end up with the construction of the MR fixture prototypes.

Once all the constituent elements of the fixture, i.e. fluids, magnetic circuits and structural components, have been developed in WPs 2 and 3, the **final phase** of the project will be focused on **refining and improving the performances of the fixture prototyped and their embedded fluids** and on overcoming the problems that may arise from their use in an industrial environment. This way, in **WP5** the **setup** of the **fixture** already built will be done and extensive testing will be carried out in order to detect and solve any problems that may arise under real industrial conditions. Moreover **WP4** will make use of these experiments to **optimize the MR** fluid formulations developed in WP2 in order to obtain a definitive MR fluid that provides best operational performances and that is capable of being produced in large batches. Finally the achieved performances in the manufacturing process using the MR fixture will be evaluated from a techno-economical point of view.

Apart from the technical workpackages of the project another non-technical workpackage is envisaged and will be as important as the technical ones in attaining the project objectives. The **management WP (WP0)** will ensure that the project successfully achieves its stated objectives on time and within budget and, consequently, will run throughout the duration of the project.

1.3 Problems encountered during the reporting period

An enlargement of 2 months of the project was as asked to the Project Officer and accepted by her. The enlargement was required to implement improvements defined during the experimental tests performed to the prototype. As it will be explained in detail in section 2, the improvements have been developed, implemented in the prototype and experimentally validated.

1.4 Overall project progress

Table 1 and Table 2 summarize the overall project progress. As it can be seen, there are no major delays. Table 3 shows the man-power effort spent during the 26months of the project per workpackage and participant.

Task	Description	Partners involved	% expected	% completed	Problems encountered	Actions to solve problems
1.1	Analysis of current processes and fixture employed by end-users. Identification of candidate workholding processes for introduction of MR fixture	ALL	100	100	NONE	NONE
1.2	Requirements definition for the MR fixture structure design	ALL	100	100	NONE	N0NE
2.1	Evaluation of the requirements on the MR fluids properties	ISC, FTK	100	100	NONE	NONE
2.2	Synthesis of special MR fluid formulations	ISC	100	100	NONE	NONE
2.3.	Characterization of the old and the new MR fluid properties	ISC	100	100	NONE	NONE
2.4	Conduction of investigations on a basic test stand simulating the fixture effect	ISC	100	100	NONE	NONE
3.1	MR fixture system concepts and associated operational procedures	ALL	100	100	NONE	NONE
3.2	Selection of the best options for the fixture and for the workholding methods	ALL	100	100	NONE	NONE
3.3	Detail design of the magnetic circuits and electrical part of the fixture	ZIP, FTK, SPA, INA, AIB	100	100	1 month more used to finish the task	NONE. The task is already finished

T3.4	Detail design of the fixture structures	All partners (except ISC)	100	100	3 months more used to finish the task. Tests to compare the behaviour of commercial magnetic plates and the one designed in the project have been performed. The design of the fixture depends on the magnetic plate selected.	The task is already finished
T3.5	Manufacturing and assembly of the MR fixture prototypes	All partners (except ISC) and mainly FTK, ZIP, AIBE & Röemheld	100	100	2 months more are needed to finish it	Hundreds of experimental tests performed in small parts to check and to improve the behaviour of the MR fluid.
T4.1	Improvement of the MR fluid properties o the basis of basic and advanced experiments	ISC	100	100	NONE	NONE
T4.2	Upscaling of the MR fluid synthesis and investigations of the reproducibility of the material properties	ISC	100	100	NONE	NONE
T4.3	Synthesis and delivery of batches of MR fluids in sufficient quantities	ISC	100	100	NONE	NONE
T5.1.	Setup of the fixture. Preliminary tests. Problems detection and resolution. improvements implementation	ALL	100	100	2 months more are needed to finish it	The task is already finished
T5.2	Final tests and validation of the fixture under real industrial conditions.	ALL	100	100	2 months more are needed to finish it	The task is already finished

Table 1. Monitoring of the tasks in progress

TASK		FAT	ISC	ZIP	SPA	HIG	ROE	INA	AIB
		PARTNERS MAN - MONTHS							
T0.1	Coordination and management	6							
T1.1	Identification of candidate workholding processes for introduction of MR fixture	1	1	1	2	2	2	2	2
T1.2	Requirements definition for the MR fixture structural design.	1	1	1	2	2	2	2	2
T2.1	Evaluation of the requirements on the MR fluids properties.	1	2						
T2.2	Synthesis of special MR fluid formulations.		5						
T2.3	Characterization of the old and the new MR fluid properties		5						
T2.4	Conduction of investigations on a basic test stand simulating the fixture effect		4						
T3.1	MR fixture system concepts and associated operational procedures	3	1	3	3	3	3	3	3
T3.2	Selection of the best options for the fixture and for the workholding methods	2		2	2	2	2	2	2
T3.3	Detail design of the magnetic circuits and electrical part of the fixture	2		9	1			1	6
T3.4	Detail design of the fixture structures	8		2	2	2	5	3	6
T3.5	Manufacturing and assembly of the MR fixture prototypes	5		8	1	1	5	1	3
T4.1	Improvement of the MR fluid properties on the basis of basic and advanced experiments		3						
T4.2	Upscaling of the MR fluid synthesis and investigations of the reproducibility of the material properties		2						
T4.3	Synthesis and delivery of batches of MR fluids in sufficient quantities		2						
T5.1	Tests of the fixture. Problem detection. Improvement implementation.	2	1	1	5	4	4	5	4
T5.2	Final tests and evaluation of the fixture under real industrial conditions.	1			6	4	2	6	4
TOTAL		32	27	27	24	20	25	25	29

MONTH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
DELIVERABLES					D2			D3					D1, D4, D5							D6				D7, D8, D9		
MILESTONES			M1					M2					M3													

Table 2. Overall project progress

PERIOD: Month 0 - Month 26		TOTAL PROJECT	FATRONIK	SPASA	HIGHFTECH	ROEMHELD	AIBE	IMA-METAV	ISC	ZIP
WP0: Coordination and management	Actual WP total	6	6							
	Planned WP total	6	6							
WP1: Definition of end-user requirements definition	Actual WP total	27,5	2	4	4	3,5	4	6	2	2
	Planned WP total	26	2	4	4	4	4	4	2	2
WP2: Development of MR fluid formulation for the fixturing system	Actual WP total	17	1			0			16	
	Planned WP total	17	1			0			16	
WP3: Fixture design and construction	Actual WP total	110,8	22	9	8,3	14	19,5	12	2	24
	Planned WP total	107	20	9	8	15	20	10	1	24
WP4: Final improvements and upscaling of the MRF synthesis	Actual WP total	6				0			6	
	Planned WP total	7				0			7	
WP5: Testing and validation of the MR fixture	Actual WP total	48,1	3	10	8,6	3	10,5	11	1	1
	Planned WP total	49	3	11	8	6	8	11	1	1
TOTAL	**Actual WP total**	**215,4**	**34**	**23**	**20,9**	**20,5**	**34**	**29**	**27**	**27**
	Planned WP total	**212**	**32**	**24**	**20**	**25**	**32**	**25**	**27**	**27**

Table 3. Person Month status table for the reporting period

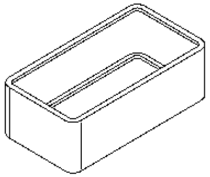
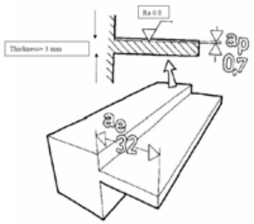
2 WORKPACKAGES PROGRESS OF THE PERIOD

2.1 Workpackage 1: End-user requirements definition

Task 1.1. Analysis of current processes and fixture employed by end-users. Identification of candidate workholding processes for introduction of MR fixture

Status: finished

The end-users of MAFFIX consortium (SPASA, HIGHFTECH and IMA_METAV) have analysed their current parts and selected two that seem to be suitable to be fixed with a MR fluid based fixture. All of them have compiled reports including a detailed description of their parts, the characteristics of the current fixtures, the disadvantages of the current process and the improvements expected after using the fixture developed in MAFFIX project. A summary of this information has been gathered in the next table:

End-user	Part Description		Disadvantages of the current fixturing system
IMA-METAV	 PART 1A	Components of a compressor bump. Serial production **Material**: aluminium alloy (Al-Si 12 or Al-Si 12 Cu1 Mg1) **Dimensions**: diameter of 200 mm and height of 50 mm **Characteristics**: it is a foundry part that has to be machined in 2 opposite sides. Due to its stiffness is not needed to fix its total height.	- It involves the using of 5 fixtures (3 for turning and 2 for boring) - the time needed for fastening the pieces in the fixture represents the 25% of the total machining time - the basic errors determined by the positioning and fixing of the parts in the devices, accumulated with a great number of fixtures, can lead to the tolerance infringement - the quality of the part execution is dependent mainly on the operator’s skill
IMA-METAV	 PART 1B	Components of a compressor bump. Serial production **Material**: aluminium alloy (Al-Si 12 or Al-Si 12 Cu1 Mg1) **Dimensions**: diameter of 120 mm and height of 23 mm **Characteristics**: it is a foundry part that has to be machined in 2 opposite sides. Due to its stiffness is not needed to fix its total height.	
HIGHFTECH	 PART 2	Aeronautical part for testing. **Material**: aluminium AL 7075-T6 **Dimensions**: a thin container of 160x85 mm section, 50 mm of height and thickness of 1 and 3 mm. **Characteristics**: the initial part is a solid piece. After a roughing machining, the inner and outer sides must be finished.	- The main problem of actual fixtures is the need of designing a dedicate fixture for each item - It is a part that has to be machined in several sides - Due to its geometrical characteristics, it is likely to suffer from vibration and deformation. Its small thickness with its close tolerances means a difficult process.
HIGHFTECH	 PART 3	An aluminium thin wall protruding from a main body **Material**: Aluminium **Dimensions**: see next figure **Characteristics**: A new concept of fixturing system is proposed. It is a combination of traditional and MRF fixture where the MR fluid is used to increase the performances of the fixture itself during some critical operation. For example, MR Fluid could be used to increase the rigidity of the part during the final machining in case of this area that can’t be easily clamped by traditional mechanical systems.	- Due to its geometrical characteristics, it is likely to suffer from vibration and deformation. Its small thickness with its close tolerances means a difficult process.

SPASA	 **PART 4**	Secondary structural element which supports the exterior and aerodynamic panels which are interchangeable (and therefore have a very strict tolerance requirement). **Material**: titanium **Initial dimensions**: T shape 73,15x32x51 mm (WxH) and 845 mm long **Final dimensions**: T shape 69x28 mm (WxH) and 834,193 mm long **Characteristics**: The most difficult thing in this system is how to hold the part because the curved profile must be really well placed on the surface but it will not be completely flat until the first roughing is done. The extrude profiles have a near net-shape (non perfect form) and to assure the tolerances of the finished parts, considering also the memory effect of Titanium, and the geometry and cutting forces it is necessary to moor the part in a free state, without introducing any forces into the part. Any forces introduced during the mooring will appear after machining, as deformation.	- Four fixturing tooling are needed nowadays to manufacture the part which means high time consuming in fixturing tooling change. - It is need a dedicate fixture for each part
SPASA	 **PART 5**	End of a specific aeronautic rod **Material**: stainless steel part **Dimensions**: 45x20x11 mm **Characteristics**: the tooling must allow the manufacturing of several parts at the same time. Currently, 5 are fixed in the same fixturing system.	- The main problem of actual fixtures is the need of designing a dedicate fixture for each item. Parts with small differences in geometry required a different tooling in order to assure the proper positioning and mooring.

Fixture manufacturers (ROEMHELD and AIBE) and FATRONIK have analysed the parts proposed by end-users. They think there are two possible configurations of the MRF fixtures: bath configuration and multi-pin configuration. In a bath configuration the part is immersed in the MRF and in the multi-pin configuration the MRF is used as a hydraulic medium. In their analysis, these partners have thought about the advantages and disadvantages of using a bath configuration or a multi-pin configuration. They have given their remarks and have chosen the parts most suitable for them for being fixed with the new fixture.

On the other hand, taking into account the description of the parts provided by end-users, Fatronik has formulated some questions to MRF experts with the aim of knowing if MRF can fulfill the requirements desired in two cases, when a bath configuration and a multi-pin configuration is considered. A template has been filled by each expert on MRF (ISC, ZIP) for each part and for a bath configuration / multi-pin configuration. The questions of the template are:

- Is the MR Fluid compatible with the material of the part?
- How the MR Fluid can be removed from the part once the machining has finished?
- Analyse the forces provided by the MR Fluid. Is the MR Fluid able to support the cutting forces? How many litres are needed to provide the requested forces?
- Estimate the electromagnetic field needed to provide the requested forces. How easy and how costly is getting that magnetic field?
- Estimate the cost of solution taking into account the MR fluid and the magnetic field
- Analyse the deformation of the MR Fluid under cutting forces
- Analyse the deformation induced in the part by the fixture based on MR Fluid
- Analyse the behaviour of the MR Fluid under ambient temperature changes of aprox 15ºC
- Analyse the behaviour of the MR fluid when the electrical power is shut down. Is the MR fluid still fixing the part when the electrical power is shut down?
- Estimate the dimensions of the container taking into account the size of the part to be fixed and the quantity of fluid needed.
- Analyse if the MR fluid could create any hazard to the machine operator during manufacturing and assembly operations and during maintenance and storage (electrical shock, dangerous magnetic field

The experts on MRF (ZIP and ISC) have explained in detailed the characteristics of both possible configurations using MRF: bath configuration and multi-pin configuration and have given their opinion about the most promising parts to be fixed with a MRF based fixture.

Taking into account the remarks done by the fixture manufacturers and the experts on MRF, two parts have been selected. These two parts are considered to be the most suitable ones to be fixed with a MRF based fixture. **The parts selected are: PART2 (aluminum thin container) and PART4 (titanium T-profile).**

Task 1.2. Requirements definition for the MR fixture structure design

Status: finished

As the two parts selected belong to Highftech and Spasa respectively, both have defined the requirements that the MR fixture must fulfill. The requirements include specifications for:

- Function
- Structural performances
- Operator safety
- Machine and piece safety
- Handling
- Accuracy
- Environment

2.2 Workpackage 2: Development of magnetorheological fluid formulations for the fixturing systems

The main objective of this workpackage is the **development of special MR fluid formulations** which are appropriate for the requirements of the fixture processes. The profile of material properties has to be adapted to the method and to the design of the fixture systems.

The spectrum of properties of an MR fluid (i.e. mechanical strength in the magnetic field, sedimentation stability, etc) depends on its composition and the production process. This variability gives the opportunity to adapt the material properties to the individual conditions of the fixture systems. According to the objectives MR fluid formulations guided by the requirements of the fixture process will be developed in consecutive steps. Starting with an MR fluid with already known composition the properties will be improved by the variation of the components (magnetic particles, carrier liquid and chemical additives). The material properties more relevant for the fixture have to be determined by rheological investigations as well as by basic experiments.

Task 2.1. Evaluation of the requirements on the MR fluids properties which have to be derived from the method and design of the fixture processes as well as the known behaviour of other MR fluids

Status: Finished

The requirements of the MR fluid must be related to the fixture process. Bath and multi-pin configuration have different characteristics so it is necessary to select the type of configuration before defining the requirements of the MR fluid. The whole consortia decided in T3.2 to use a bath configuration for the two fixtures that will be designed in the project.
Taking into account the external forces applied to the MR fluid and that a bath configuration will be used, Fraunhofer-ISC established the following requirements to the new MR fluid:

- Yield stress > 30 KPa at 400 mT; > 50 KPa at 600 mT
- Base viscosity can be high, but MR fluid must be able to flow without magnetic field
- Sedimentation stability > 1 month
- Temperature range 0ºC to +50ºC
- Compatibility with other materials (i.e. workpiece, construction materials)
- No health risks for operators

Task 2.2. Synthesis of special MR fluid formulations

Status: finished

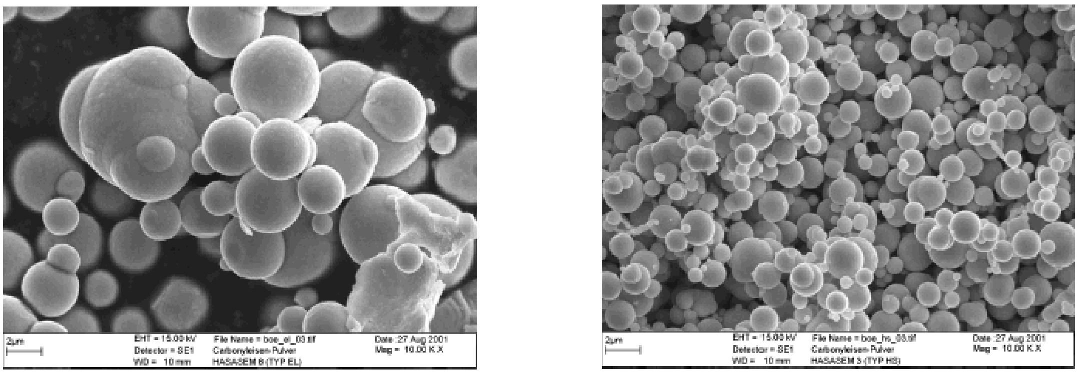
This task has been started with the synthesis of a MR fluid with already known composition as a reference point for comparison with improved materials. This reference MR fluid has been selected, manufactured and delivered to ZIP for first fixture tests. The properties of further MR fluids with different compositions can be compared in order to quantify the progress of the material development.
Several MR fluids with strongly different compositions have been synthesized. The synthesized MR fluids differ each other from

a) The percentage of magnetisable particles (material, concentration, size distribution, shape, etc). MR fluid with a percentage of magnetisable particles between 30% and 55% has been synthesized.
b) Carrier liquid (chemical composition, viscosity, temperature dependence, volatility, etc). Oil-based and water-based MR fluids have been synthesized.
c) Additives (nature and concentration of dispersants, stabilizers, anti-oxidants, etc)

As a result of this variation of the composition, the properties of the reference MR fluid and two new MR fluids whose behaviour best suit the requirements established in T2.1 are shown in the Table 4. The increase of the content of iron particles is aimed to enhance the shear stress of the MR fluid in the magnetic field. The shear stress is most strongly influenced by the concentration of magnetisable particles which can interact with each other. The shear stress in the magnetic field is mainly responsible for the fixture force which has to reach a value as high as possible.

MR fluid	**MA 1 (Reference)**	**MA 28 (New)**	**MA 240 (New)**
Carrier liquid	Silicone oil	Silicone oil	Silicone oil
Iron particle content	35 vol.%	55 vol.%	50 vol.%
Mean particle size	5 µm	Mixt. 2 µm + 7 µm	5 µm
Additives	Inorg. Particles	Organic grease	Grease

Table 4. Characteristics of reference MR fluid and two new MR fluids



a) **b)**

Figure 2. MR fluids with strongly different percentage of magnetisable particles a) reference MR fluid – MA1; b) improved MR fluid – MA 28

The second new MR fluid MA 240 in Table 4 has been developed recently. It could be shown that the achievable shear stress at a fixed magnetic flux density is even higher than that of the former MR fluid MA 28. This progress should be a benefit for the use in the fixture device. Both MR fluids, MA 28 and MA 240 will be tested in the prototype of the project during WP5.

The conventional MR fluids are oily-based MR fluids. Fraunhofer-ISC is working in synthesizing water-based MR fluids which main advantage is that they are more benign for the environment.

Several MR fluids with water as carrier liquid were prepared and tested. They contain different types of iron powders and a variety of stabilizing agents as well as corrosion inhibitors. An important result of these investigations was that the sensitivity of the iron powder in water to corrosion strongly depends on the quality of the iron powder. Iron powders could be identified which are less sensitive to corrosion. Furthermore, oxidation protecting agents could be found which reduce the corrosion of the iron particles. An example of the study of corrosion is revealed in Fig. 3.

As a result, a new MR fluid with an interesting profile of properties was prepared. It contains 45 vol.% iron particles and was named MA-W-252. The properties of this new MR fluid are shown in section T2.3

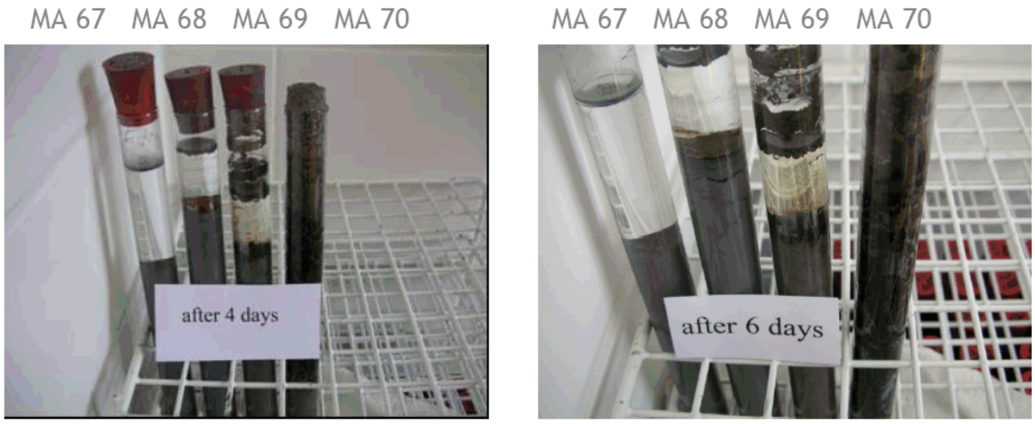


Figure 3. Water-based MR fluids: Investigation of corrosion of iron particles

Task 2.3. Characterization of the old and the new MR fluid properties

Status: finished

The reference MR fluid as well as other MR fluids with strongly different compositions in terms of the magnetic particles content inside have been characterized with respect to the following properties: shear stress and yield stress vs magnetic field strength, flowability of the MR fluid, temperature, sedimentation stability and compatibility with surrounding materials. Several oily-based and water-based MR fluids have been synthesized and their rheological properties in the magnetic field and without field, respectively, have been measured. These activities resulted into new MR fluid composition MA 28 and MR 240.

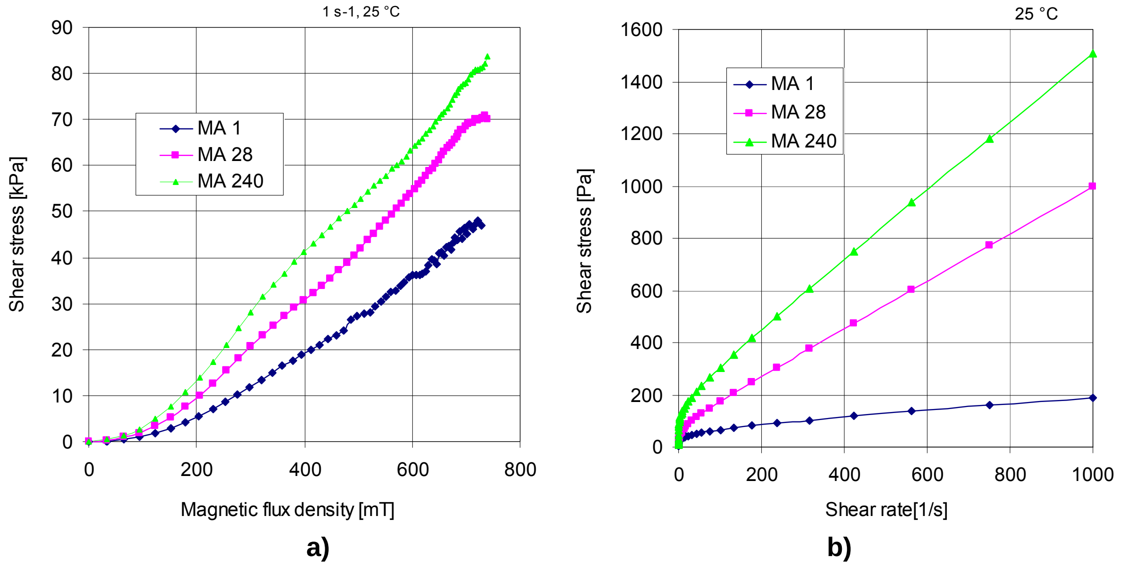


Figure 4. Oil-based MR fluids. a) Shear stress vs. magnetic flux density, b) flow curves without magnetic field

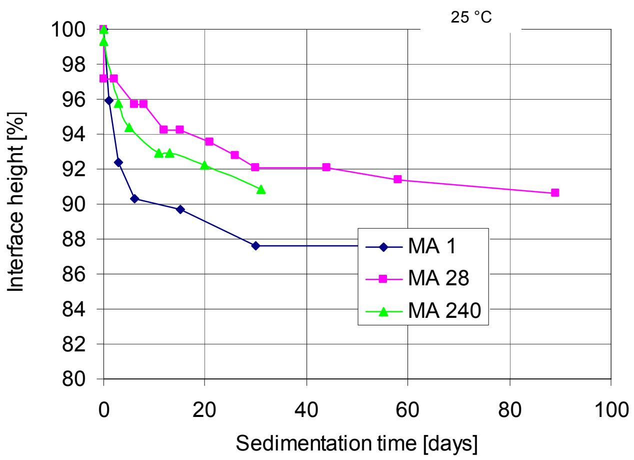


Figure 5. Oil-based MR fluids. Sedimentation stability

Fig. 4 shows the dependence of the shear stress on the magnetic flux density as well as the base viscosity without magnetic field for the reference MR fluid MA 1 and the two new MR fluids MA 28 and MA 240. MA 240 reaches the highest shear stress at a fixed magnetic flux density, which predestines this MR fluid for the fixture process. The base viscosity is relatively high, but this is not prohibitive as long as the flowability is sufficient. The sedimentation stability shown in Fig. 5 is also well acceptable.

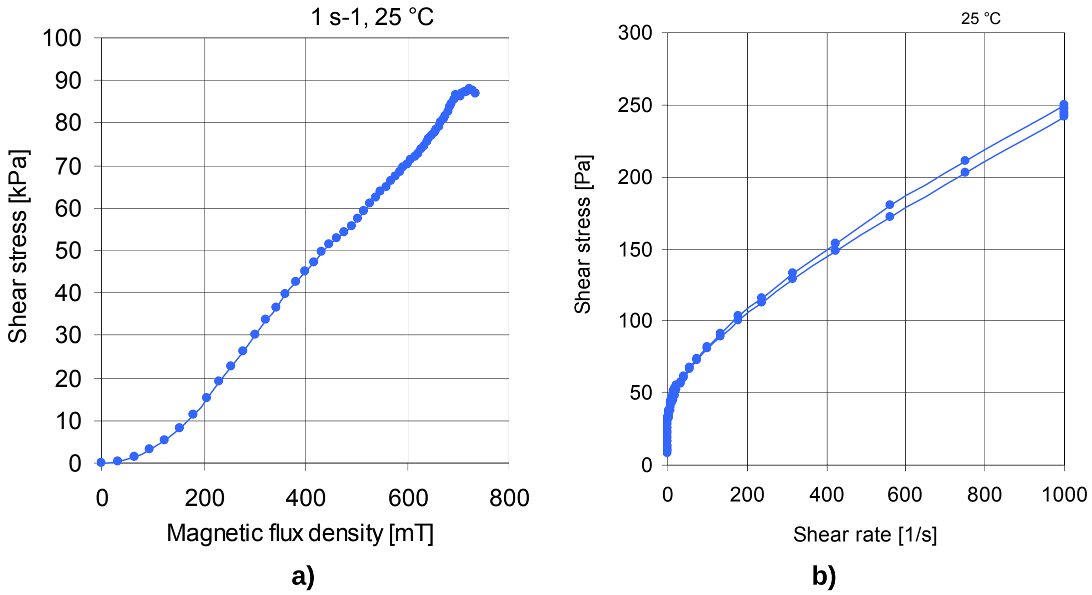


Figure 6. Water-based MR fluid MA-W 252. a) Shear stress vs. magnetic flux density, b) flow curves without magnetic field

Moreover, the properties of the new aqueous MR fluid MA-W 252 were investigated, too. Fig. 6 depicts the shear stress dependence on the magnetic flux density and the base viscosity without field. The shear stress generated in the magnetic field is even higher than that of the MR fluid MA 240 under comparable conditions. The base viscosity is relatively low, which is another advantage. The sedimentation stability is also in a good range, which is revealed in Fig. 7. However, the high volatility of water could be a problem, if the MR fluid is used in an open environment.

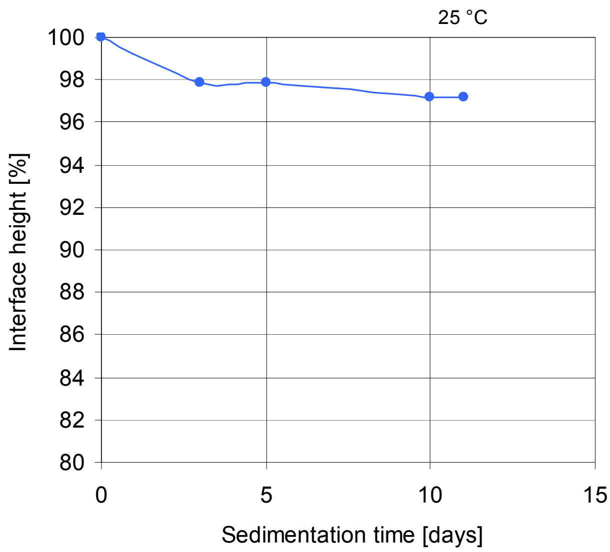


Figure 7. Water-based MR fluid MA-W 252. Sedimentation stability

On the other hand, Fraunhofer-ISC has determined the static yield stress of MR fluid MA 28 and MA 240. The yield stress of the MR fluid is an important property for the fixture process, because it determines the load on the workpiece during fixturing without significant creeping of the workpiece. A magneto-rheometer and the fixture testing device built in T2.4 have been used for determining the static yield stress.

Moreover, he has investigated the compatibility of the cooling liquid using by SPASA during the machining of the T-profile with the MR fluid MA 28 and MA 240. In the milling process on the workpiece part 4 at SPASA a cooling liquid is sprayed onto the milling tool in order to remove heat from the tool and to avoid overheating. Because in the new fixturing procedure under development in the MAFFIX project the MR fluid is used in an open bath configuration there was some concern that the contact of the cooling liquid with the MR fluid could eventually deteriorate the properties of the MR fluid and affect the fixturing process. In order to clarify this point a study of the miscibility of the cooling liquid with the MR fluid was performed. It can be concluded from the investigations that the contact of the cooling liquid with the MR fluid MA 28 & MA240 should not cause severe problems in terms of the dilution of the MR fluid and the consecutive decrease of the yield stress and the holding force in the magnetic field. However, this conclusion is not generally true for all MR fluids. The new MR fluid based on water as the carrier liquid, which is currently under development, will be miscible with the cooling liquid RU Meta used by SPASA in the milling process.

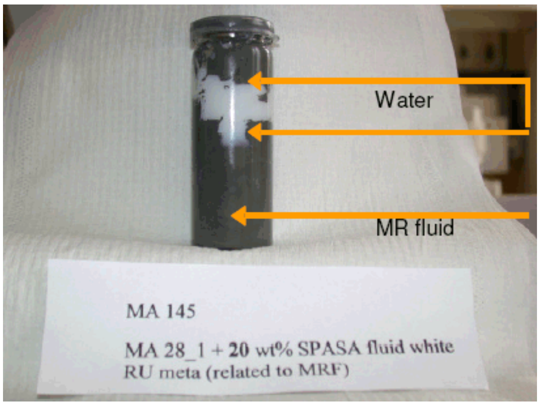


Figure 8. MR fluid Ma28 mixed with 20% of cooling liquid RU Meta.

Finally it has been studied the flowability of the MR fluid MA 28. The MR fluid MA 28 developed for the application in the fixture device has primarily to show a large yield stress in the magnetic field in order to generate high fixture forces. This property requires a large content of iron particles in the MR fluid. On the other side, the high iron content also leads to a large base viscosity of the MR fluid without the application of the magnetic field. The large base viscosity could eventually cause problems in the filling of the volume containing the MR fluid in the fixture device if the gap width of this volume is quite small. In this case it could happen that the volume is not completely filled with the MR fluid and the required fixture force on the workpiece cannot be achieved due to voids in the MR fluid. This is especially relevant for the workpiece part 2 whose fixture device designed in the MAFFIX project possesses extended gaps with a width of 2 mm, which are filled with the MR fluid. It can be concluded from the experiment that the filling of narrow gaps in the fixture device with the MR fluid MA 28 is principally possible. However, in order to avoid even small voids in the MR fluid volume, it is recommended to press the MR fluid into the gap with a certain pressure or to suck the MR fluid into the gap by applying vacuum or depression.

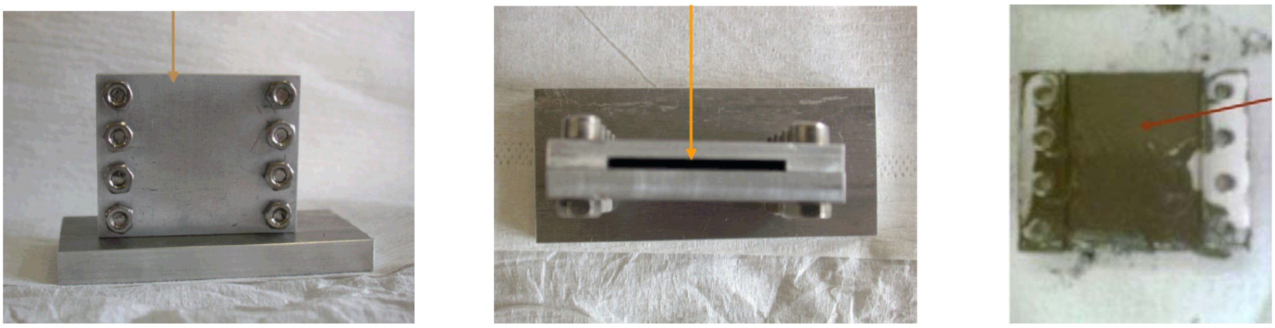


Figure 9. Aluminum container with gap filled by the MR fluid, gap width 2.4 mm, assembled (left) and MR fluid at the inner surface after dissambling (right)

<u>Task 2.4. Set-up of a basic experiment simulating the fixture effect on selected simple objects in a container filled with the MR fluid.</u>

Status: finished

ISC has optimised the fixture testing device built in the first months of the project in order to check the performance of an MR fluid if the applied shear stress is reduced below the yield stress. If the applied force (shear stress) surmounts the holding force of the MR fluid, the plate starts to move and to be pulled out of the MR fluid. This limit of the shear stress where the plate starts to move is called “static yield stress”. If the load on the plate is below but near the limit of the yield stress, it must be expected that the plate exerts some slow motion which is called “creeping” in the following. In order to achieve a high accuracy during the machining process, it is necessary to avoid this creeping or to reduce it to an acceptable extent. In order to evaluate the behaviour of an MR fluid under such conditions, corresponding experiments applying lower shear stresses than the static yield have been performed.

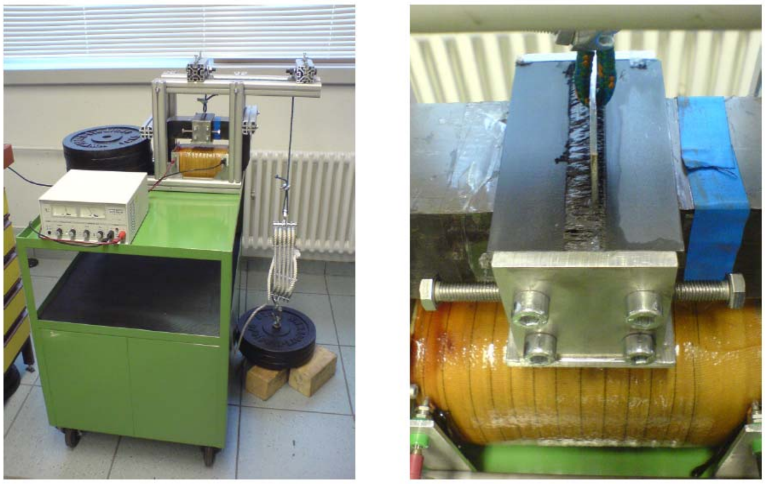


Figure 10. Device built by ISC for testing the performance of MR fluids

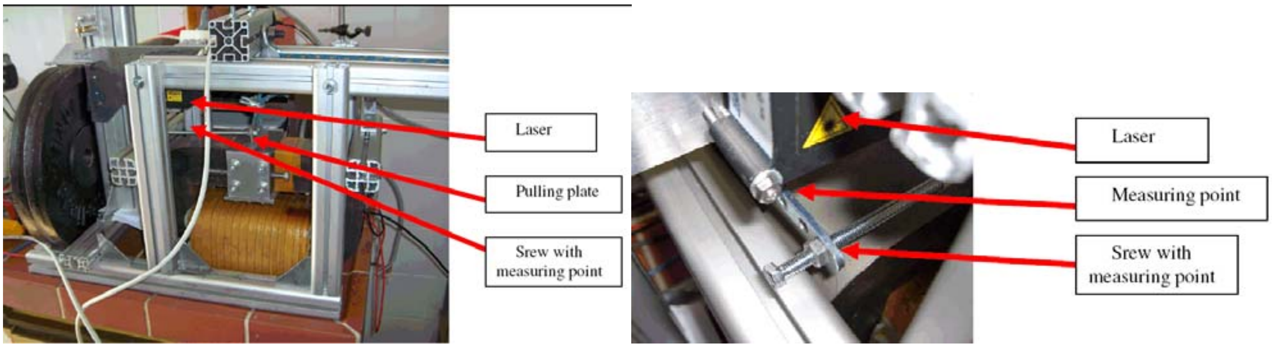


Figure 11. a) Fixture testing device with laser triangulator attached b) Detailed view of the measuring point attached to the pulling plate

In order to record the displacement of the pulling plate which is immersed in the MR fluid, a position sensor was attached to the device. Because the displacement of the plate is expected to be very small, a high accuracy of the sensor is required. Therefore it was decided to attach a laser triangulator which can measure displacements with an accuracy of 1 µm. The laser is attached to the frame of the device. Because there was not enough space above the pulling plate, a screw is fixed on the pulling plate. On this screw the reflection surface for the laser beam is located. The optimised testing device is presented in Fig. 11.

All measurements were performed on the selected MR fluid MA 28. In order to evaluate the creeping behavior of the MR fluid a constant load was applied to the pulling plate for one hour. Two series of experiments were conducted. For the first series of tests forces corresponding to 55 % of the yield stress at the selected magnetic field strength (flux density) were applied to the MR fluid. The second series of tests was performed with forces corresponding to 75 % of the yield stress of the MR fluid. Within both series the MR fluid was tested under the influence of three different magnetic flux densities (300 mT, 400 mT and 500 mT, respectively). The displacement of the pulling plate was recorded over one hour. The results of the two test series are presented in Fig. 12 and Fig. 13.

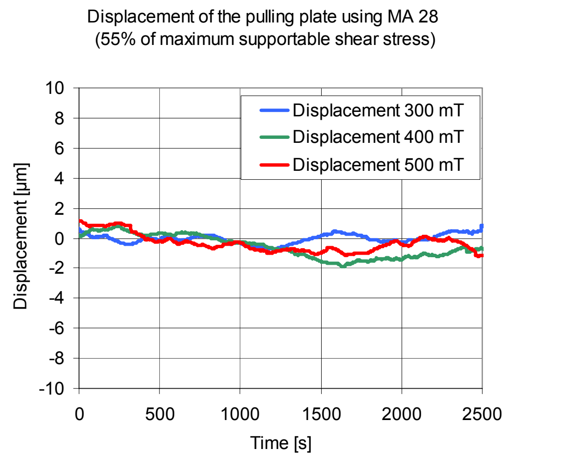


Fig. 12: Displacement of the pulling plate loaded with 55 % of yield stress

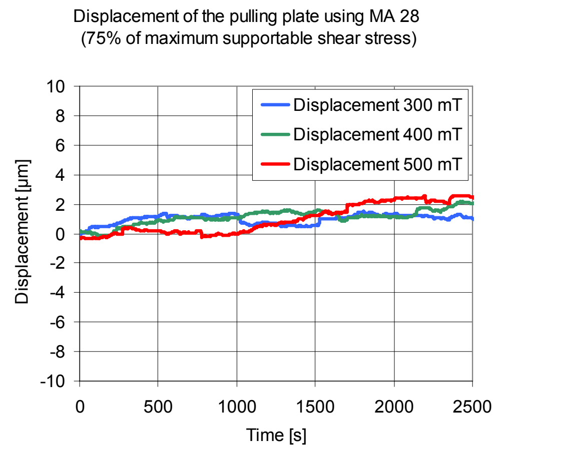


Fig. 13: Displacement of the pulling plate loaded with 75 % of yield stress

In the first series where 55 % of the yield stress of the MR fluid was applied, no creeping effects of the pulling plate could be observed (Fig. 12). In the other series of experiments with a load of 75 % of the yield stress, only small creeping effects of the pulling plate were recorded (Fig. 13). The measured displacements of the pulling plate are in the range of 2 µm and very close to the limit of the accuracy of the laser triangulator. Such small effect should not disturb the milling process on the workpiece in its accuracy.

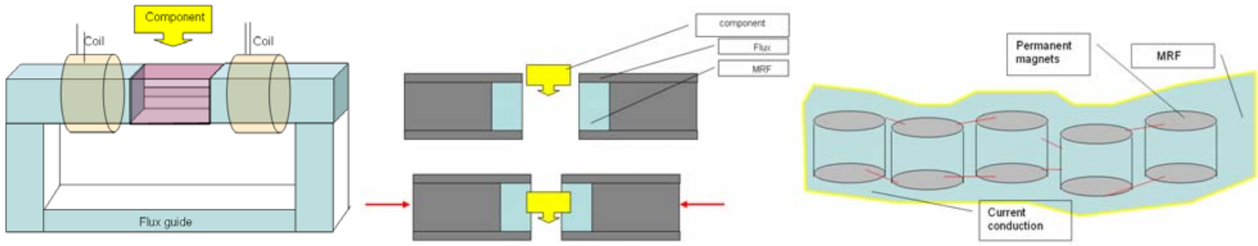
From the measurements, it can be concluded, that as long as the applied shear stress is less than 75 % of the yield stress of the MR fluid no disturbing creeping effects have to be expected. In order to avoid the risk of creeping it is recommended to keep the load on the workpiece at or below 75 % of the maximum load corresponding to the yield stress of the MR fluid where the workpiece begins to move significantly.

2.3 Workpackage 3: Fixture design and construction

Task 3.1. MR fixture system concepts and associated operational procedures

Status: finished

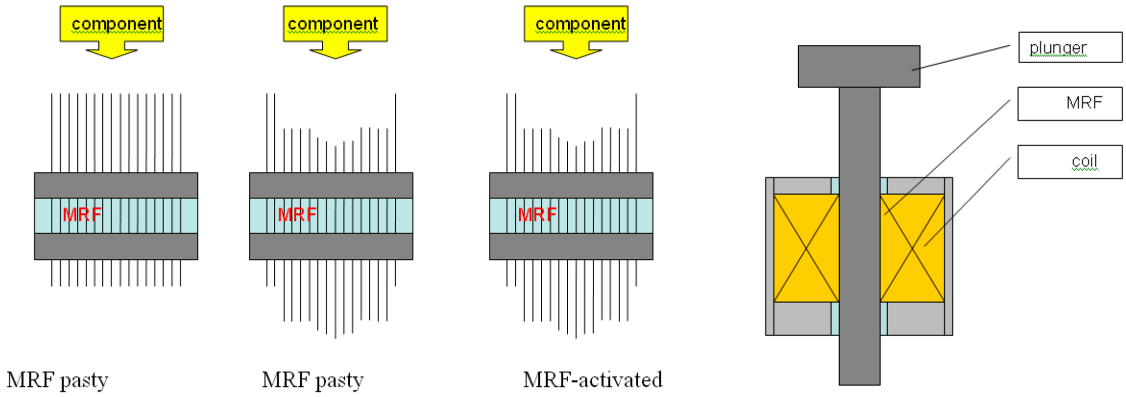
ZIP has made several proposals to sustain parts by a fixture based on MR fluids. These proposals are variants from the basic “bath” configuration and multi-pin. In the basic bath configuration the fluid is in direct contact with the workpiece. Under a magnetic field, the MRF creates mechanically sustainable structures that fix the workpiece. If the magnetic fluid is separated from the workpiece by a thin foil, a MRF cushions are got which main advantage is that it is not need to clean the workpiece after fixing it. If, besides using a thin foil to separate the fluid from the workpiece the permanent magnets are located inside the foil, MRF mats are got. These concepts are shown next:



Basic bath configuration **MRF cushions concept** **MRF mats concept**

Figure 14. Different conceptual designs of the MR fluids based on a bath configuration

Regarding multi-pin configurations, several versions are proposed. First, a direct clamping of the pins by the MRF itself, second a system where each pin is a hydraulic piston and the displaced MRF flows into a compensating reservoir. Closing only one valve at the reservoir could block all pins. But it would still be possible that one pin could be pressed down if another has the opportunity to rise. This leads to the third multi-pin solution where each pin is designed as a double piston and has its own valve.



Multi-pin fixture concept. **MRF valve**

Figure 15. Different conceptual designs of the MR fluids based on a multi-pin configuration

Experts on MRF (ZIP and ISC) have analysed the advantages and disadvantages of the different concepts and have sent them to the consortium that has studied the different solutions and has compiled a summary table for the 2 workpieces selected in WP1 (PART 2 and PART 4).

PART2

Configuration	Field generation	Mechanical effort	Deformation to workpiece caused by fixture	Flexibility (size of workpiece)	Flexibility (shape of workpiece)	function of MR fluid
Bath	--	++	++	-	++	Stabilisation Vibration reduction
Multiple PIN	+	-	+	+	-	Fixation
Cushion + Vice Jaw	-	+	++	+	+	Stabilisation Vibration reduction
Multiple PIN + Vice Jaw	+	--	+	++	-	Fixation

PART4

Configuration	Field generation	Mechanical effort	Deformation to workpiece caused by fixture	Flexibility (size of workpiece)	Flexibility (shape of workpiece)	function of MR fluid
Bath	+	++	++	--	++	Fixation
Multiple PIN	+	-	+	-	-	Fixation
Cushion + Vice Jaw	+	+	+	+	+	Fixation
Multiple PIN + Vice Jaw	+	--	+	++	-	Fixation

Fixture manufacturers (AIBE and ROEMHELD) and Fatronik have also proposed new conceptual designs for the parts selected in WP1.

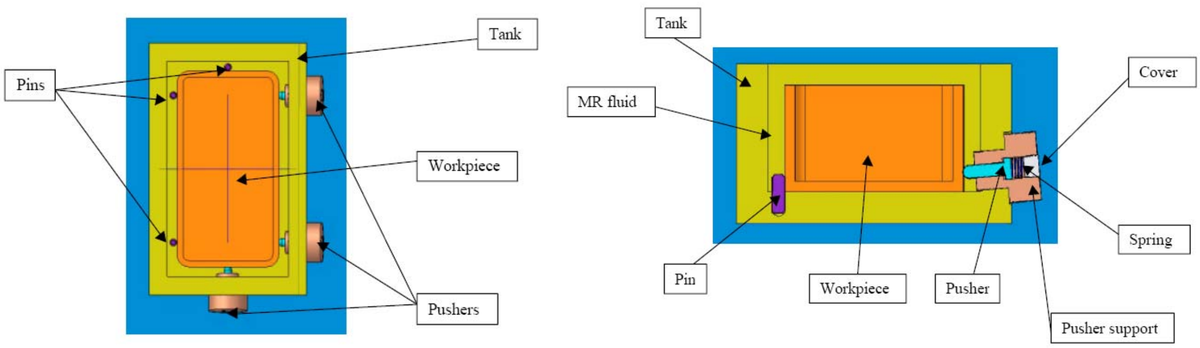
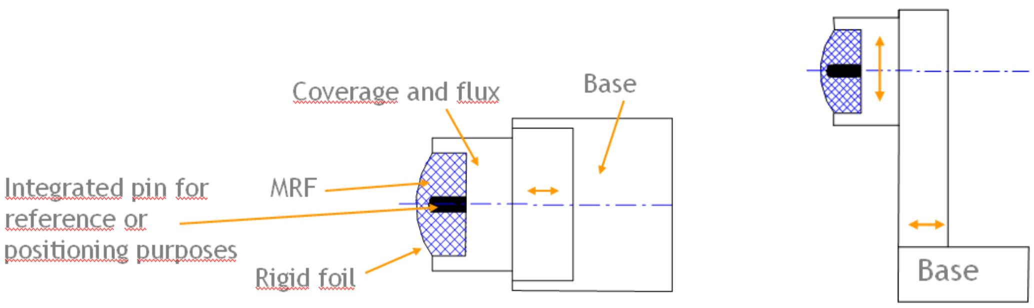


Figure 16. Conceptual design proposed by AIBE for PART 2 (bath configuration)



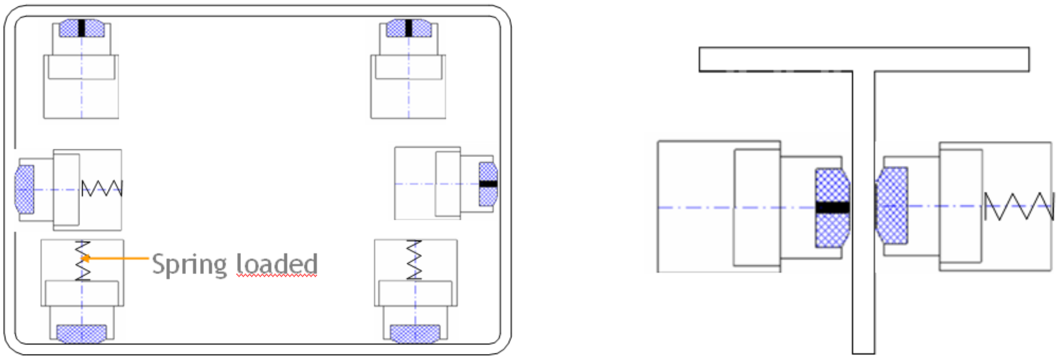


Figure 17. Conceptual design proposed by ROEMHELD for PART 2 and PART 4 (modular device with MRF cushions)

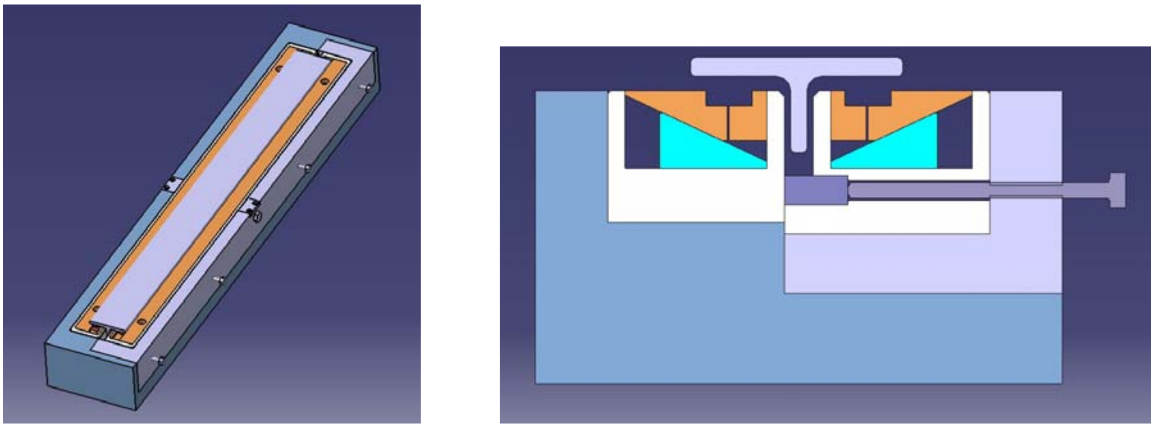
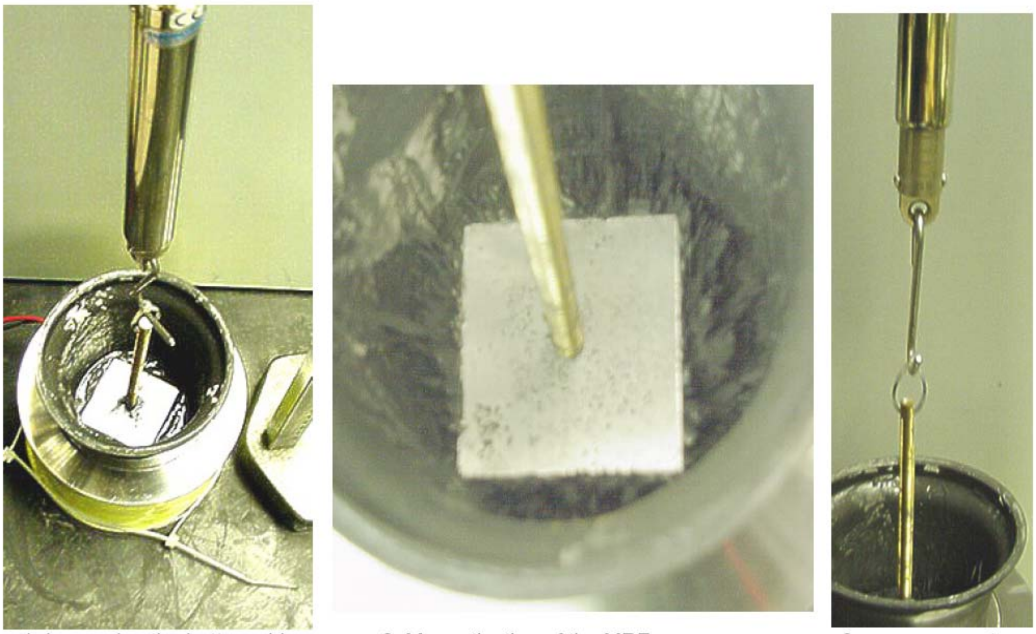


Figure 18. Conceptual design proposed by FATRONIK for PART 4 (bath configuration)

On their hand, end-users (Spasa, Highftech and Ima-Metav) have analysed and evaluated the conceptual designs proposed by the different partners.

Finally, ZIP has performed some basic experiments that clarify basic ideas about how to generate the magnetic field and how to support attractive forces. Before starting the project, they already knew that under a magnetic field the MRF could support compressive and lateral forces but no testing had been done about supporting attractive forces.

The experiments done in WP3 have shown that a MRF bath is able to sustain attractive forces even to a non-magnetic piece. This may come from an air sealed contact between the MRF and the workpiece.



1. Immersion the bottom side 2. Magnetisation of the MRF 3. measurement

Figure 19. Pictures of the preliminary tests performed by ZIP

Task 3.2. Selection of the best options for the fixture and for the workholding methods

Status: finished

Once the partners of Maffix project have defined different conceptual designs for the 2 parts selected in WP1, the best configuration for each part has been selected as well as the number of prototypes that will be built. To take this decision the next steps have been followed:

- Define technical and economical criteria in order to select the best MRF-based fixtures. This task has been done by end-users –IMA-METAV, HIGHFTECH, SPASA-
- Select the best conceptual design of fixture for PART2 and PART4. Select only one option per part. This task has been done by end-users taking into account the remarks done by fixture manufacturers and experts on MRF.
- Perform a technical and economical analysis for the conceptual design selected for PART 2 and PART4. This task has been done by Fatronik, ZIP and ISC.
- Decide how many and which prototypes will be built in the project taking into account the budget available. This task has been done by the whole consortia.

The conclusions of this task are the following:

- Taking into account that the main characteristic of **PART2** (aluminum container) is the compliance of its vertical walls, **all the partners agree with the fact that the bath configuration is the most suitable concept for this fixture.**
- **Bath configuration has been also selected for designing the fixture for PART4** (titanium T-profile). This time, both multi-pin and bath configurations are suitable for reducing the actual number of fixture tooling and fixturing tooling change time and for ensuring the tolerances of the design; that are the main requirements for PART4's fixture. However, end users don't find any advantage of using MRF valves against hydraulic valves.
- The economical analysis has been performed for the conceptual design of the fixtures that is in their preliminary design phase. As far as the design concept changes, the economical analysis must be updated. From this analysis has been concluded that **there are enough resources in the project to design and manufacture both fixtures.**

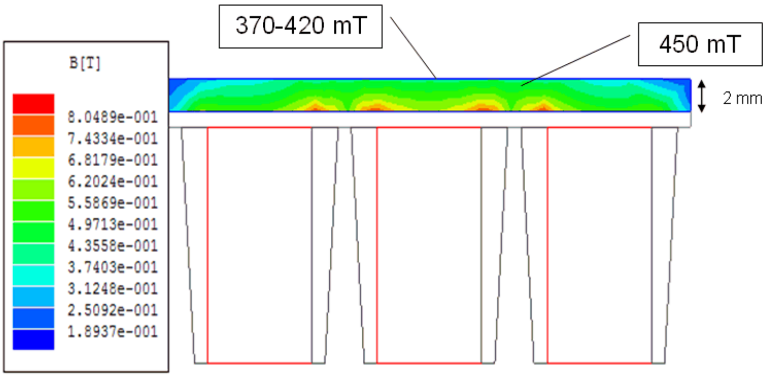
Task 3.3. Detail design of the magnetic circuits and electrical parts of the fixture

Status: finished

ZIP has analysed 3 possibilities to generate the required magnetic field: a) using electromagnets; b) using permanent magnets and c) combination of electric and permanent magnets. Permanent magnets fulfil the objectives of simplicity, compactness and economics and therefore, they will be chosen in the first approach. The main problem of the permanent magnets is how to switch-off the field. ZIP, Aibe and Fatronik have worked on this issue and have found a proper solution that will be explained later.

ZIP have designed and simulated a magnetic plate that it is able to generate a flux density around 400 mT with a MR fluid film of 3 mm. This value is very likely to be enough to support the external forces applied to the workpieces.

The magnetic plate is composed by a non-magnetic plate with permanent magnets inserted in it. Glued to the permanent magnets are steel parts to increase the magnetised area. The type and size of the permanent magnets, the size of the steel parts and the distance between magnets are some of variables that have been analysed in the simulation process. A sample of the magnetic plate has been built and tested. The experimental results correspond very well to the theoretical values. In the experimental test, it has been checked that the tensile forces can be also sustained.



a) **b)**

Figure 20. a) A sample of the magnetic plate for the experimental testing; b) MEF simulations of the magnetic plate

Different alternatives to switch-off the magnetic field have been studied and analysed. The selected alternative consists on separating the magnetic plate from the MR fluid. To avoid the MR fluid moves together with the magnetic plate, the MRF will be in a non-magnetic container called separating plate. In this design there is a gap between the workpiece and the magnetic plate which the sum of the MRF film and the thickness of the separating plate. The magnetic field must be high enough to generate a magnetic flux density around 400 mT in the bottom of the workpiece. MR fluid film and the thickness of the separating plate are another two variables to take into account in the design phase.

Theoretical simulations have been done to check the distance between the workpiece and the magnetic plate needed to switch-off the magnetic field in the MR fluid.

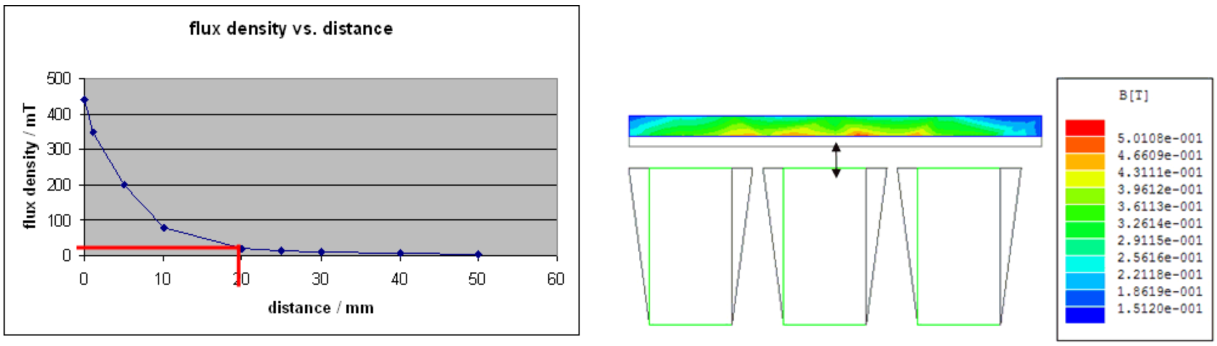


Figure 21. Switch-off the magnetic field. Sensitivity of the magnetic flux density against gap between magnetic plate and workpiece

An optimisation of the magnetic plate has been done. The type and size of the permanent magnets, the size of the steel parts, the distance between magnets and the maximum thickness of the separating plate and of the MR fluid film have been defined.

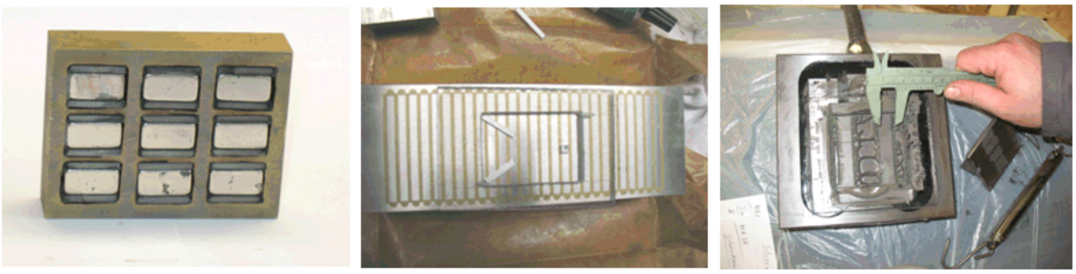
ZIP has checked that the magnetic plate designed can be used for the two fixtures of the project.

Task 3.4. Detail design of the fixture structures

Status: finished

In the mid-term meeting it was decided to compare experimentally the behaviour of different magnetic plates and analyse their advantages and disadvantages. In particular, it was decided to test 3 types of magnetic plates: 1) the magnetic plate designed in the project in T3.3; 2) a commercial magnetic plate where the magnetic field is activated mechanically; 3) a commercial magnetic plate where the magnetic field is activated electrically called electropermanent plate. The design of the fixture structures was postponed until the experimental tests were finished because the fixture structures are highly depended on the type of magnetic plate used.

Next, you can see the 3 magnetic plates tested and their main characteristics.



	ZIP plate	Permanent plate	El./perm. plate
Pole intervals	13 mm x 17 mm	6.1 mm	40 mm(?) (→ 25 mm possible)
Field strength	300 mT (1 mm)	170 mT (at surface)	~105 mT max. (at surface)
Remarks	strongest field separating mechanism necessary	easy to handle easy to clean	possibility to magnetise at any possible level

Figure 22. Pictures of the 3 magnetic plates tested and their main characteristics

ZIP has performed the tests to the 3 magnetic plates. In addition to magnetic plates other variables have been taking into account:

- type of MR fluid: 3 types were analysed MA1; MA28_1 and MA_240
- Thickness of the MR fluid (0 mm, 0.5 mm, 1 mm, 1.5 mm and 2 mm). A gap of 0 mm means that the workpiece was immersed just to the ground but keeping a very small bath.

After the experimental partners of MAFFIX project have discussed about the main criteria to select the most suitable magnetic plate. The following table sums up the conclusion of the discussion.

	Swtichable mechanically plate	Electropermanent plate	Zip's design with permanent magnets
Able to generate the required magnetic flux density to support attractive and compressive forces	VERY GOOD	VERY GOOD	VERY GOOD
Able to generate the required magnetic flux density to support shear forces	GOOD	POOR: Optimization is needed. Shear forces should be supported by external devices	GOOD
Easy to switch ON and OFF the magnetic field	GOOD	VERY GOOD (easy to get different value of magnetic field)	POOR (move back the permanent magnets are needed to switch off the field)
Easy to handle	GOOD	VERY GOOD	POOR
Able to be built in long sizes	POOR (with long plates is not possible to switch ON and OFF the magnetic field)	VERY GOOD	VERY GOOD

The partners have decided to bet on the electropermanent plate but to do the following improvements:

- redesign the plate by reducing the distance between magnets from 30 mm to 15 mm
- use the minimum thickness of MR fluid as possible
- design reference devices able to support shear forces

The discussion about the magnetic plate included also the number of prototypes to be built. The 2 key points of the project that will guarantee the success of the new fixtures are: to get a suitable MR fluid and to get a magnetic plate able to generate the required magnetic flux density. After analysing the two workpieces selected in the project, it was concluded that the same working principle of the MR fluid will be used for both of them (bath solution). Moreover, the same MR fluid is also recommended as well as the same magnetic plate. Regarding the external forces, more severe forces must be supported in the fixture for the titanium T-profile than in the aluminium container. Therefore, if the good results are obtained in the testing of the fixture for the T-profile, good results will be obtained in the fixture of the aluminium container. Taking into account of all these points, ***it was decided to build and test the fixture that will work under more severe conditions and to provide the design for the other fixture.*** It will be built the fixture for the titanium T-profile.

Next, it is showed the final version of the design of the fixtures for workpiece 4 (Titanium T-profile) with the electropermanent magnetic plate. The design of the fixture has been simplified due to the use of a magnetic plate easy to be magnetised and de-magnetised. The design of the fixture has been mainly done by Fatronik, Spasa, Aibe and Röemheld. ZIP and Ima-Metav have checked the design and have also contributed with their comments.

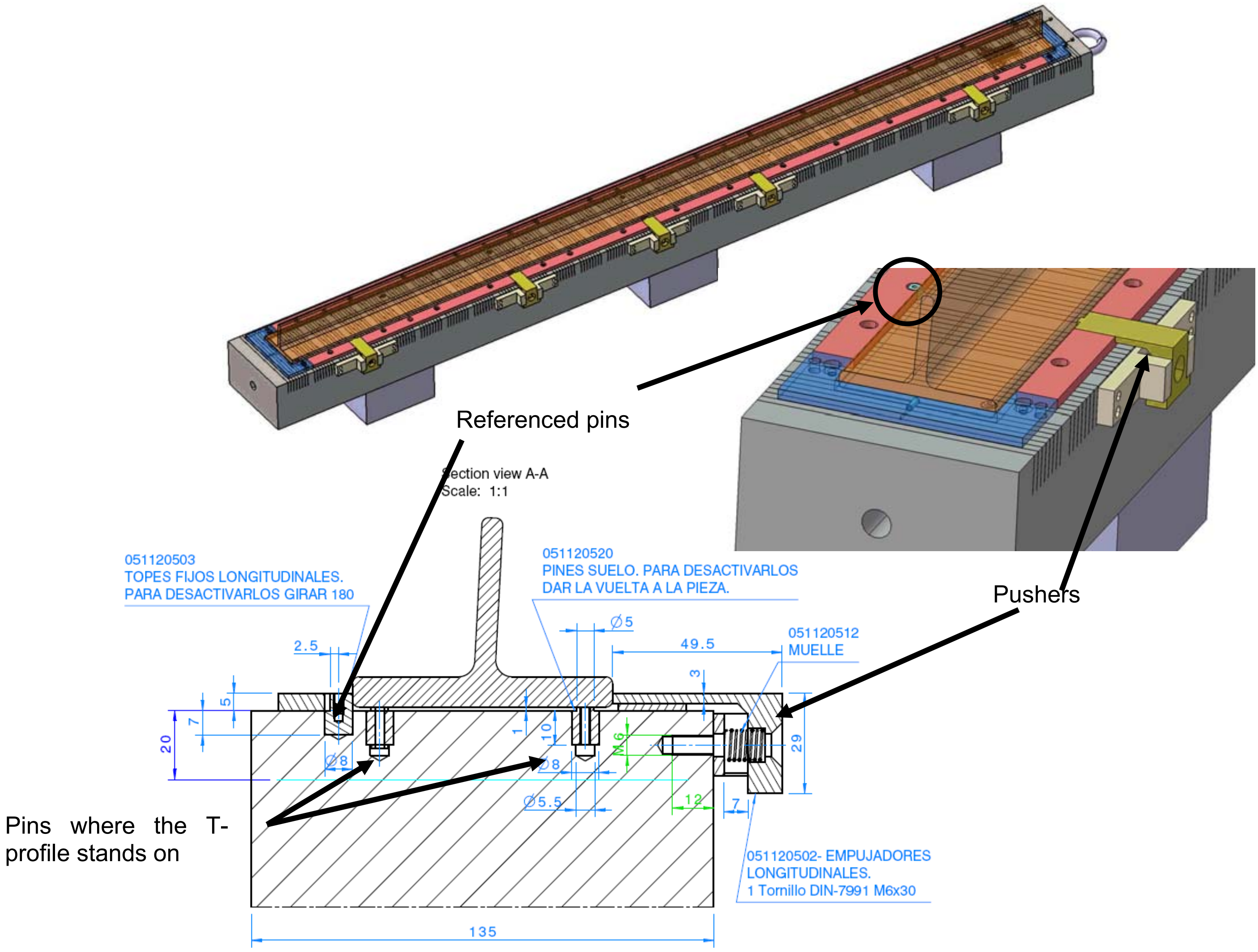


Figure 23.·3D detailed design and a detail of the assembly drawing of the fixture for the titanium T-profile

The fixture consists on a frame formed by 4 walls that will be tied to the magnetic plate by means of screws. The MR fluid is poured to the fixture before the workpiece is located. The MR fluid is in direct contact with the magnetic plate and the workpiece is immersed some millimetres (around 4 mm) in it.

According to SPASA needs, the T-profile must stand on 3 pins that will be screwed directly to the frame. The height of the pins will be the same as the height of the MR fluid between the T-profile and the magnetic plate. Apart from the pins the T-profile must be located by means of referenced devices that will be also tied to the frame. The referenced devices have been designed to be able to support shear forces. The referenced devices are composed by 2 pieces, one of them is a reference pin and the other one is a pusher. Both will be screwed to the magnetic plate. The number of referenced pins and pushers have been decided taking into account the lengths of the different profiles that will be fixed there. Moreover, additional plates have been designed to adapt the frame to the lengths of the profiles. Experts on MR fluids (Fraunhofer-ISC and ZIP) recommend that the distance between the frame and the workpiece is the smallest as possible to get the maximum magnetic flux density on the MR fluid.

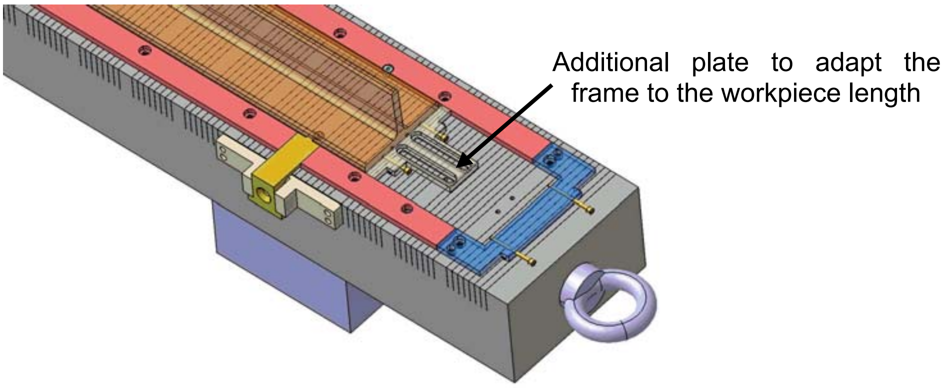


Figure 24.·3D detailed design of the fixture for the titanium T-profile. Detail of the additional plates to adapt the frame to the length of the workpiece

The fixture for workpiece 2 (aluminium container) has also been simplified as a consequence of using the electropermanent plate. The design of the fixture has been mainly done by Fatronik, Highftech, Aibe and Röemheld. ZIP and Ima-Metav have checked the design and have also contributed with their comments.

The fixture is mainly composed by 4 magnetic plates and a support. The magnetic plate contacts directly to the workpiece, or better said, the perimeter of the magnetic plate contacts the workpiece. The magnetic area of the plate is separated 1 mm or 1.5 mm from the workpiece and the MR fluid will be between them.

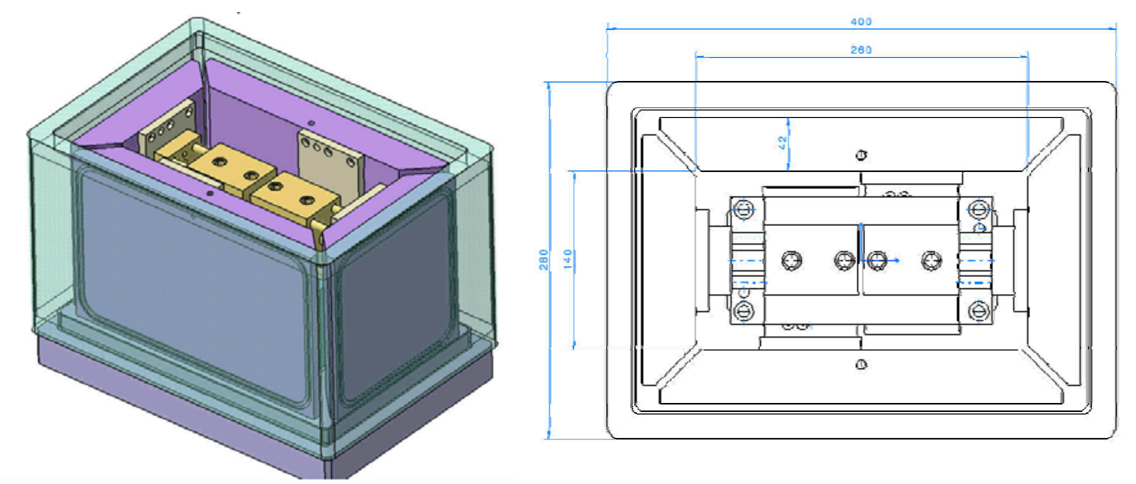


Figure 25.·3D detailed design of the fixture for the aluminium container.

The easiest way to move the magnetic plate would be using hydraulic cylinders. However, due to space limitations it is not possible to mount the right cylinders to support the working forces. The recommended alternative is to mount the magnetic plate in small guiding units or to tie manually the magnetic plates to the supports. In both cases the interface (grey parts) that joins the magnetic plate to the support is screwed directly to the support. Their holes will have a play to be able to adapt itself to the workpiece. An extra part (rose one) will be used to fix the magnetic plate in the right position.

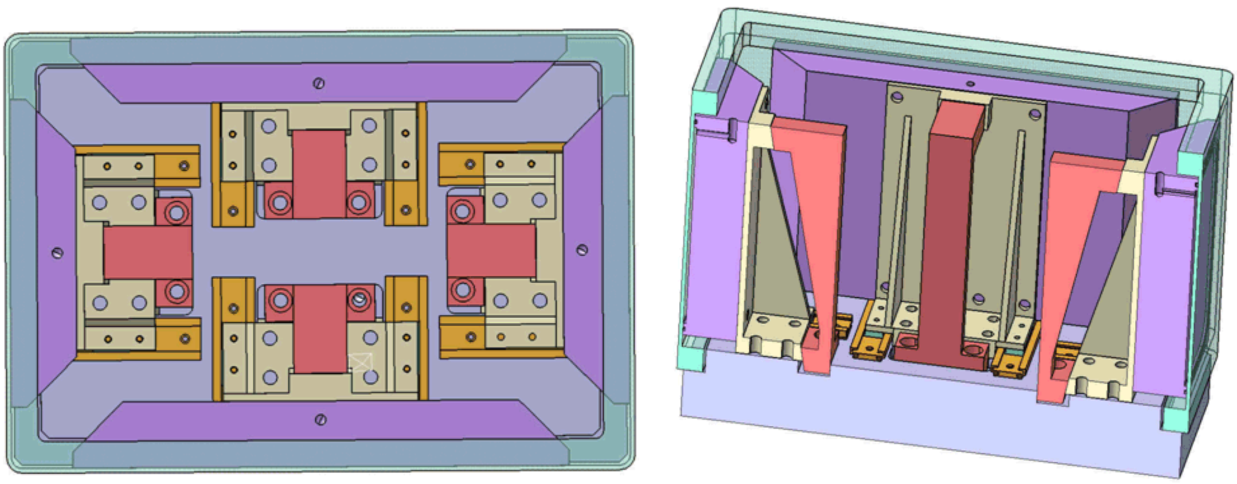


Figure 26.·3D detailed design of the fixture for the aluminium container.

Task 3.5. Manufacturing and assembly of the MR fixture prototype

Status: finished

Roemheld and ZIP have redesigned the commercial electropermanent magnetic plate to adapt it to the requirements of MAFFIX prototype. As it is a modification of an already industrialized plate, it will be quickly launched at the market if the experimental tests to be performed in WP5 give good results. The manufacturing drawings are done and the magnetic plate is being manufactured.

Fatronik has done the manufacturing drawings of the fixture for the titanium T-profile and those have been revised by Spasa, Highftech, Röemheld and Aibe.

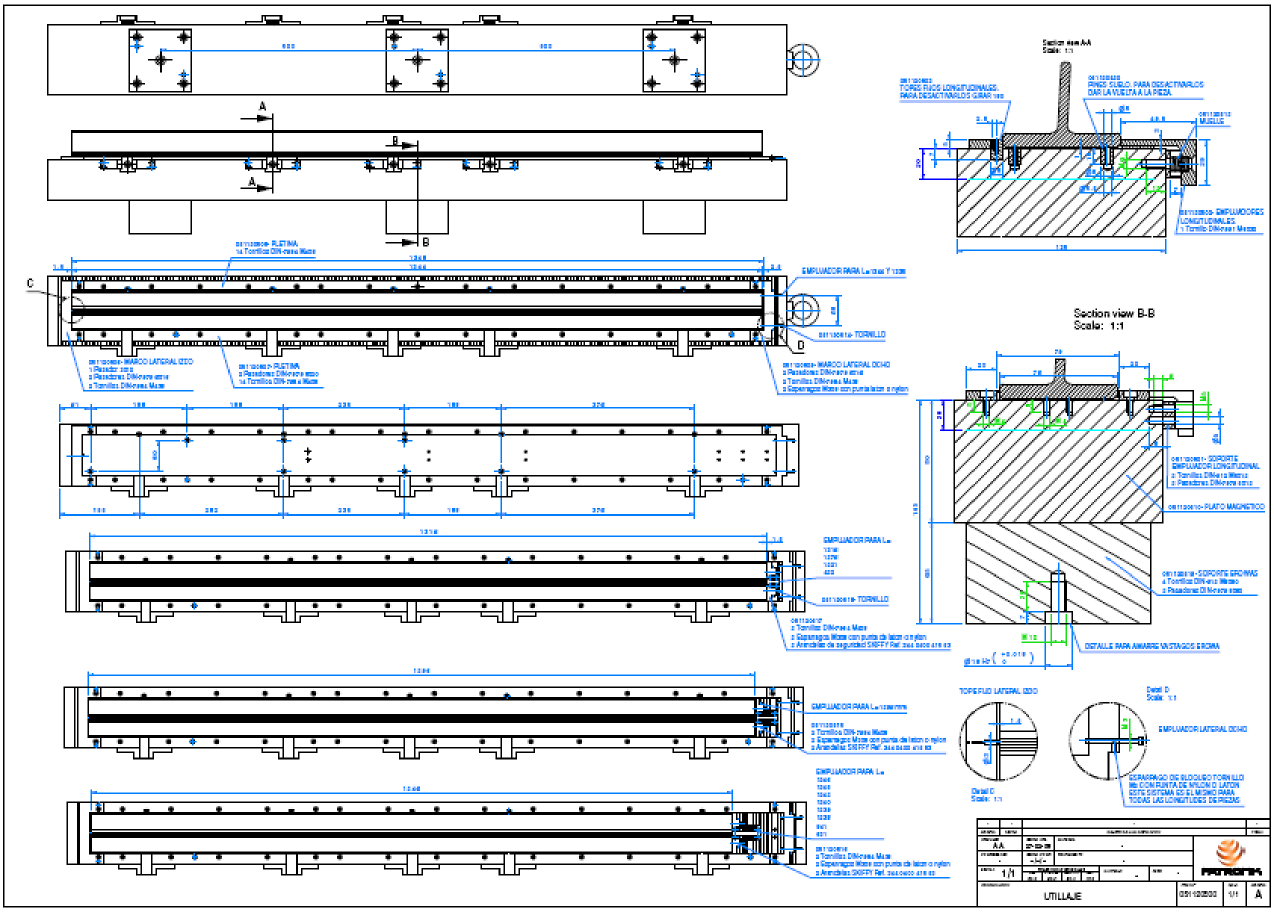
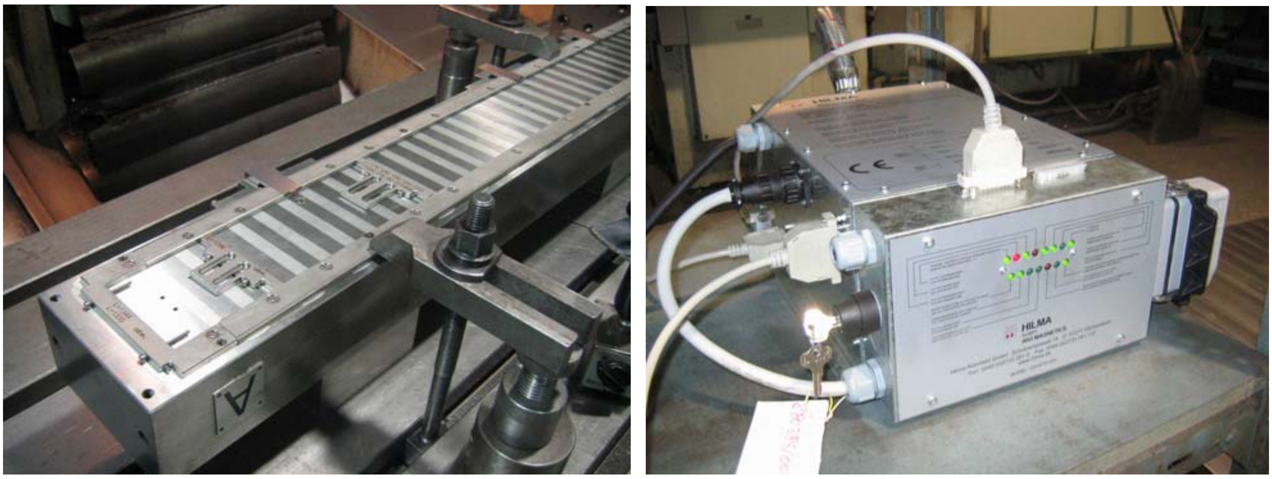


Figure 27.·Assembly drawing of the fixture, magnetic plate and supports to join the magnetic plate to the

Once the fixture and the magnetic plate have been manufactured, both have been assembled in Aibe facilities. There, the mechanical performances of the fixture have been checked.



a) b)

Figure 28.a) Setup of the MR fixture for the T-profile in AIBE facilities; b) Controller of the magnetic plate built by Hilma

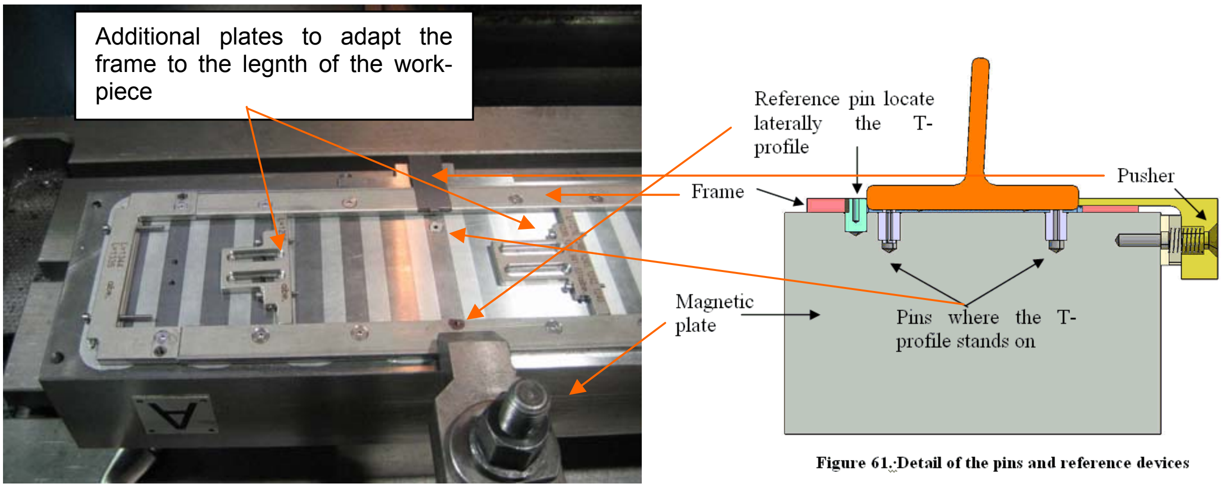


Figure 29.a) Setup of the MR fixture for the T-profile; b)·Detailed view of the MR fixture CAD 3D

Fraunhofer-ISC has already prepared 2 liters of MR fluid that will be used in the testing of the prototype. 2 types of MR fluids will be tested,: the MA_50 and the MA_240 with 55% and 50%vol of solid content (magnetic particles) respectively.

Finally, the prototype has been sent to Spasa where the experimental tests under machining loads will be performed. In Spasa, the prototype will be tested in the milling machine FP-35 from Nicolas Correa. The prototype will be tied to the machine table by means of hydraulic actuators.

2.4 Workpackage 4: Final improvements and upscaling of the MR fluid synthesis

T4.1.Improvement of the MR fluid properties on the basis of basic and advanced experiments

Status: finished

Fraunhofer-ISC has built a new experimental set-up to measure the MR squeeze mode. Thanks to this new testing device it will be possible to measure pulling and pushing forces and to apply a variable magnetic field and flux density. Moreover, it will be possible to generate the magnetic field using permanent magnets, electromagnets and a combination of both of them. The testing device built in T2.4 can only measure pulling forces and the magnetic field is variable by only generated by electromagnets.

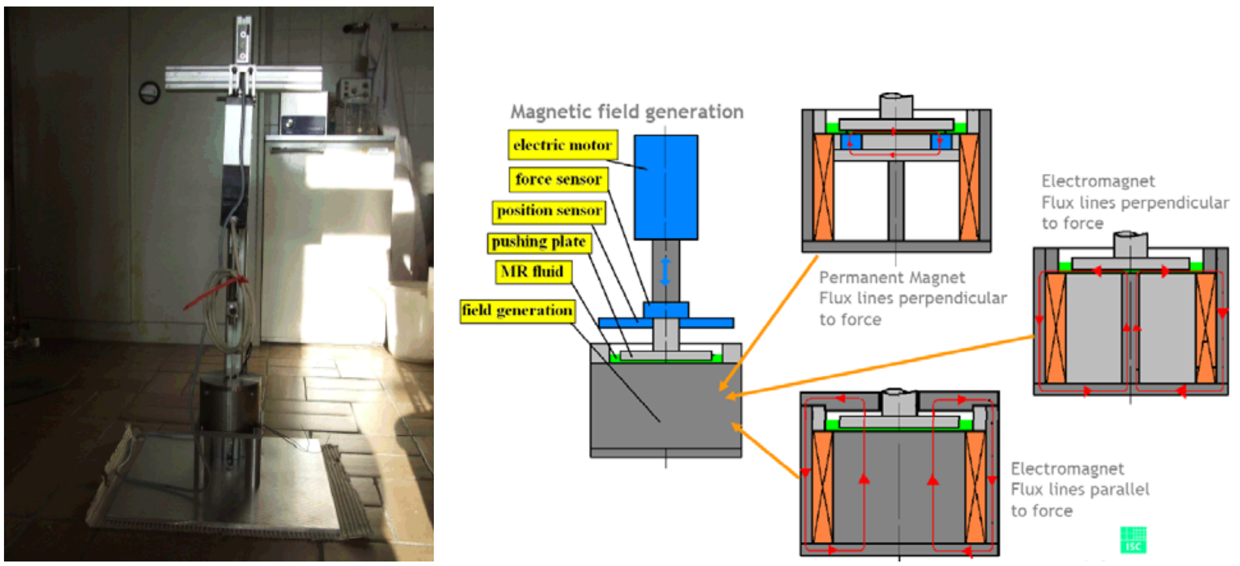


Figure 30.·New MR squeeze mode experimental set-up

With the testing device, a large number of measurements were performed. Fig. 31 presents the results of two test series which were conducted with the MR fluids MA 28 and MA 240.

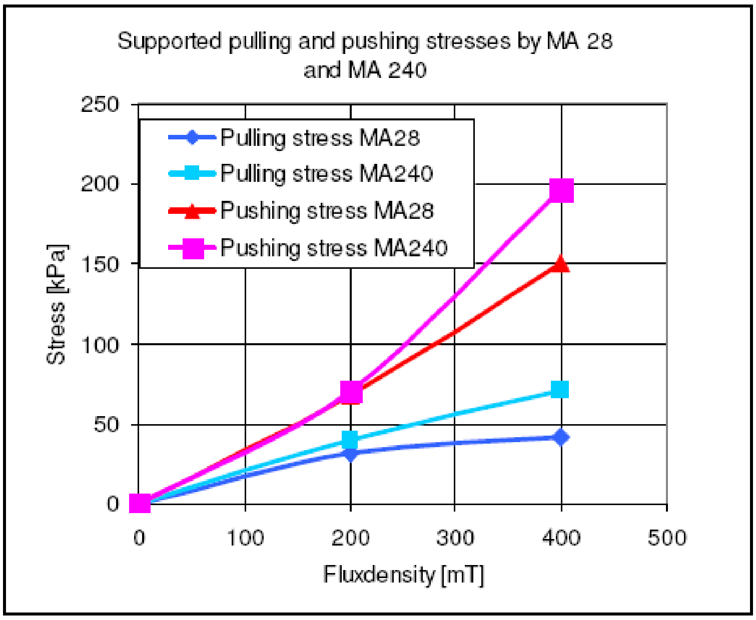


Figure 31. Supportable pulling and pushing forces of the MR fluids MA 28 and MA 240 at various flux densities

It is noticeable that the supported pushing stresses of both fluids are much higher than the supported pulling stresses. Additionally it can be seen, that the stresses supported by MA 240 are higher than the stresses supported by the fluid MA 28. These results correspond with the results which were received with the shear mode testing device. It can be concluded that both, the pushing stresses and the pulling stresses of both fluids are strong enough to generate the required holding forces for the MR fixture.

<u>T4.2. Upscaling of the MR fluid synthesis and investigations of the reproducibility of the material properties</u>

Status: finished

Fraunhofer-ISC has studied the up-scaling of the oily based MR fluid MA 28 and MA 240 up to batch sizes of 2 liters. The up-scaling process was performed in two steps. In the first step, the prepared MR fluid quantity was increased from 80 milliliters to 800 milliliters. The second step was an increase of the batch size to the final quantity of 2 liters.

For the production of the magnetorheological fluids at Fraunhofer ISC a standard Dispermat ® CN 20 (VMA Getzmann GmbH Verfahrentschnik, Germany) has been used. This device works with the dissolver principle using a high-speed rotating blade, which homogenizes the components in the MR fluid. The procedure is shown in Fig. 32.

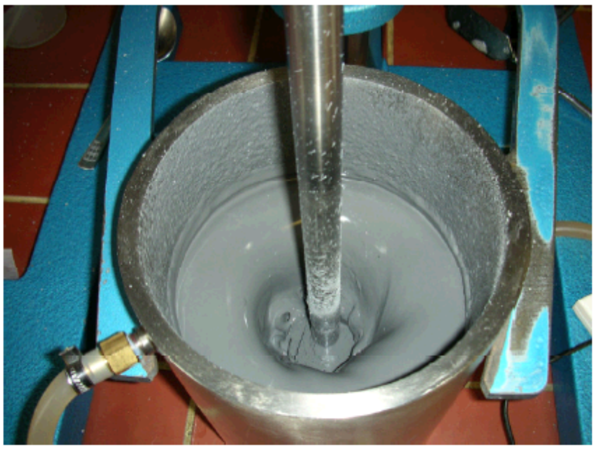


Figure 32. Procedure of the production of the final MR fluid MA 240

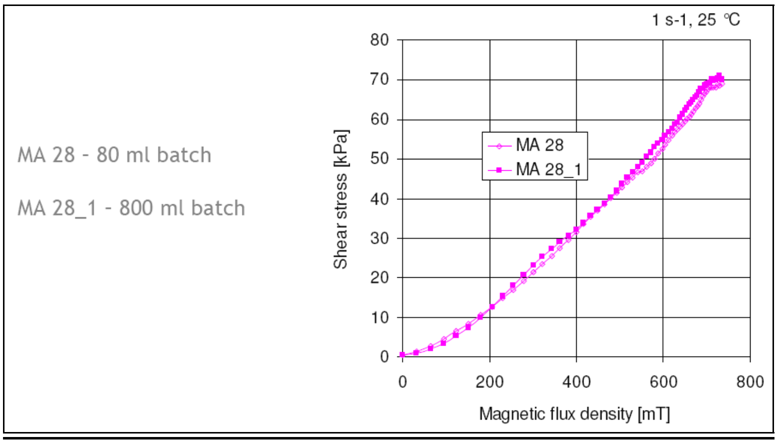


Figure 33. Dependence of the shear stress on the magnetic flux density at 25 °C and a shear rate of 1 s-1 for MR fluid samples MA 28 and MA 240 from different batch sizes

An important requirement of the MR fluid production is the reproducibility of the properties of the MR fluid in the up-scaling process. This means, that the properties of the MR fluid in the large batch should ideally be identical with those of the small sample. In many processes, the up-scaling procedure causes problems.

In case of the former MR fluids MA 1 and MA 28, it could already be demonstrated, that the up-scaling process was possible without significant changes of the relevant MR fluid properties. The same success was also achieved with the final MR fluid MA 240.

4.3. Synthesis and delivery of batches of MR fluid in sufficient quantities

Status: finished

For both new MR fluids, MA 28 as well as MA 240, batches of about 2 liter were synthesized by Fraunhofer ISC and characterized with respect to their main properties. Parts of these samples were delivered to the project partners ZIP and FATRONIK. ZIP used the MR fluid samples for experimental investigations of fixture forces under special conditions, whereas FATRONIK will distribute the MR fluids to SPASA, where it will be used in the fixture process of the long T-profile.

Table 5 gives a summary of the MR fluid batches delivered to the project partners during the project.

MR Fluid	Project Partner	Quantity	Delivery Date
MA 1	ZIP	0.5 litre	February 2007
MA 1	Fatronik	0.4 litre	June 2007
MA 28	ZIP	0.63 litre	October 2007 November 2007
MA 28	Fatronik	1 litre	March 2008
MA 240	ZIP	0.08 litre	October 2007
MA 240	Fatronik	1 litre	March 2008
MA 28 and MA 240	SPASA	1 litre 1 litre	August 2008 August 2008
MA 240	ZIP	0,5 litre	August 2008

Table 5: MR fluid samples delivered to the project partners

2.5 Workpackage 5. Testing and validation of the MR fixture

T5.1. Setup of the fixture and workholding capabilities characterization. Preliminary tests of the fixture during manufacturing cycles. Problems detection and resolution. Improvements implementation

Status: finished

The preliminary tests performed in the MR tooling have been static tests. Attractive and lateral forces have been applied to 2 T-profiles provided by Spasa: i) a short one of 422 mm length and ii) a long one of 1276 mm length. Incremental forces have been applied by means of a hydraulic cylinder until the T-profile separates from the MR fluid. The displacement of the T-profile under force has been measured by a micrometer.

The experimental tests have been performed with 2 MR fluids developed in the project in WP2, MA 28 and MA240. Both MR fluids have silicon oil as carrier liquid. On the other hand, the experimental tests have been performed by the pins on the floor of the magnetic plate ON (Gap 1 mm) and OFF (Gap 0 mm).

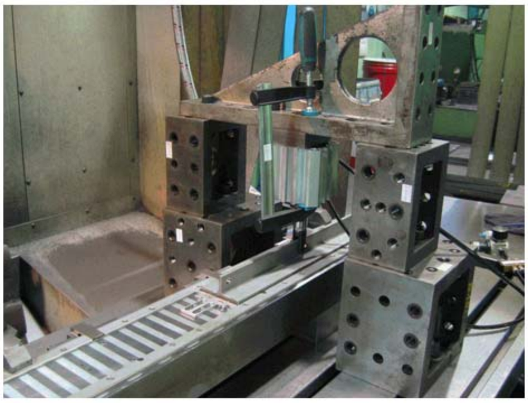
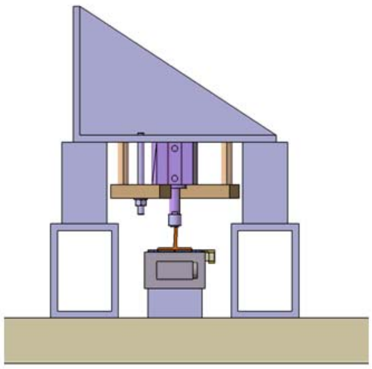



Figure 34. Setup for applying attractive forces in the T-profile

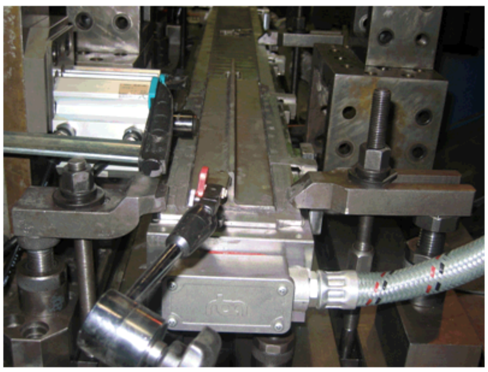
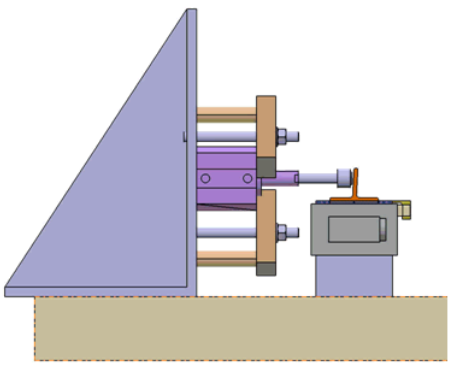



Figure 35. Setup for applying lateral forces in the T-profile

The main conclusions of the preliminary experimental tests and the improvements to be done are the following:

- The time for applying the MR fluid and fixing the profile is around 5 minutes whilst 20 min are needed to fix the profile with the conventional fixture

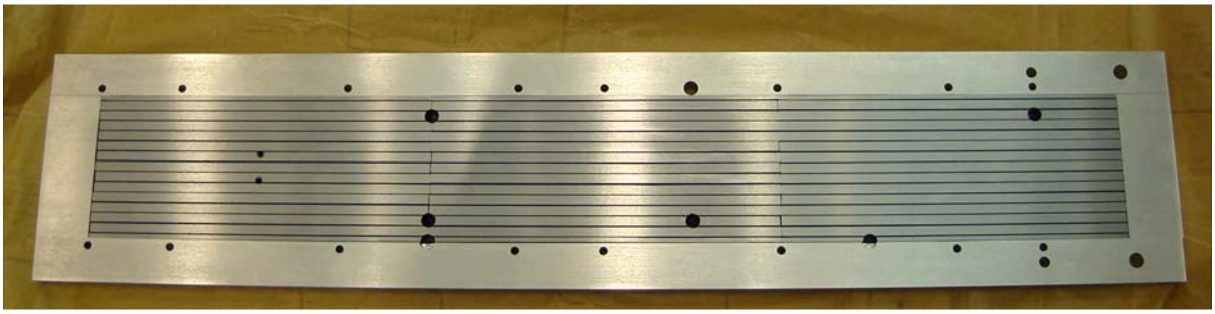
- In order to guarantee high holding forces of the prototype it is needed to have a high magnetic flux density in the area below the workpiece. Magnetic flux density out of this area must be avoided. The current plate magnetic allows “leaks” of flux density to the perimeter of the plate. On the other hand, there is high variation of the magnetic flux density from the primary and secondary poles when an uniform flux density is desired. To avoid it, LPA-ZIP proposed to **design and manufacture magnetic pole adaptors.**

- In order to guarantee high holding forces of the prototype it is also needed to seal well the space occupied by the MR fluid and avoid air burbles between the work-piece and the magnetic plate. To seal properly the space occupied by the MR fluid is recommended to **seal the seal between the mechanical parts of the fixture and the magnetic plate**, to **add enough quantity of MR fluid** to fill completely the free space between the workpiece and the fixture in the four sides and to **replace the stainless steel frame by a steel frame**.

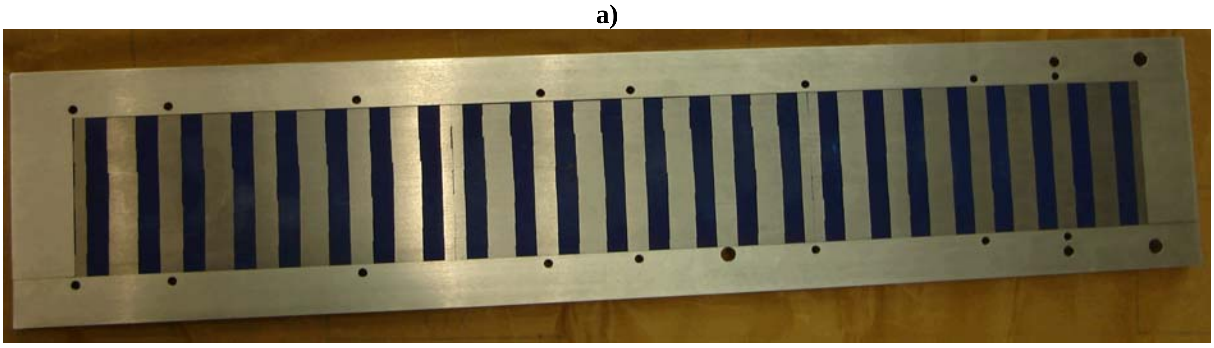
<u>Development of the magnetic pole adaptor</u>

The electro-permanent plate is the best choice to handle a MRF-based fixturing system. But the construction rules for such a plate are limiting some dimensions to values that are not ideal to be used with MR fluid. The minimum manufacturable pattern size is too large (about 50 mm instead of the needed ≈ 14 mm for a couple of poles), and the field strength is caused by the large distance between the poles not as high as favoured. This distance can not be reduced because it is needed to contain the coils necessary to switch on or off the plate.

The pole adaptor developed by ZIP is especially designed to fit the electro permanent magnetic plate to the requirements of using MR fluid as a fixturing medium. First, it changes the direction of the poles for 90 degrees. Second it reduces the pattern to 12 mm for a couple of poles and third it includes a kind of magnetically “sealing” of the long sides of the workpiece. Due to the much narrower pattern, the field strength is expected to rise by factor 3..5 (up to 250mT instead of 40..80mT) according our simulations.



a)



b)

Figure 36. a) Upper side of the pole adaptor; b) Lower side of the pole adaptor

To seal properly the space occupied by the MR fluid an avoid air burbles between the workpiece and the magnetic plate a plastic seal has been designed and built. The seal has the same area as the fixture's frame and will be mounted between the frame and the magnetic plate or pole adaptor.

Figure 37. Plastic seal to seal the space occupied by the MR fluid

The magnetic pole adaptor, the plastic seal and the frame made of steel have been built and have been mounted in the fixture as it can be seen in the next photos.

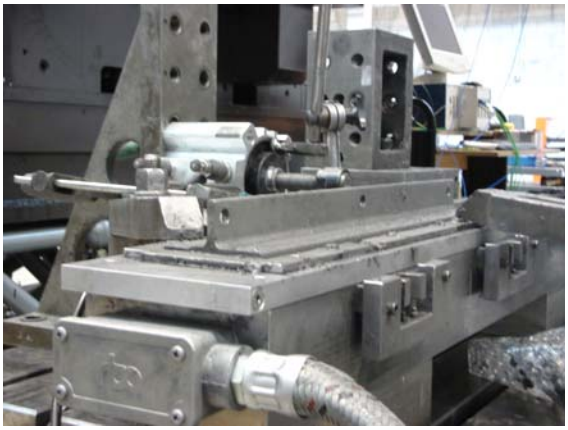



Figure 37. Photo of the pole adaptor and seal assembled in the magnetic plate

T5.2. Final tests and validation of the fixture under real industrial conditions. Evaluation of the achieved performances and techno-economical comparison with currently used fixturing methods

Status: finished

Using the same setup as in the preliminary tests, **attractive and lateral forces have been applied** to the 2 T-profiles provided by Spasa: i) a short one of 422 mm length and ii) a long one of 1276 mm length. Incremental forces have been applied by means of a hydraulic cylinder until the T-profile peeled off the MR fluid. The displacement of the T-profile under force has been measured by a micrometer.

The variables that have been considered in these tests are:

1. Pins ON vs pins OFF
2. Lateral pushers ON vs lateral pushers OFF
3. Frame made of STAINLESS STEEL vs frame made of STEEL
4. Seal ON vs seal OFF
5. MR fluids: MA 240 (oil-based), MA28 (oil-based), MA 1 (reference fluid, oil-based) & MA W252 (water-based)
6. Pole adaptor ON vs pole adaptor OFF

The main conclusions obtained are the following:

1. In general, it can be concluded that the effect of having the pins ON (i.e. gap of 1 mm) means a decrease of the maximum forces supported of about 25 kg. It is recommended analysing the possibility of not having the pins activated.
2. The effect of pushers is null under attractive forces. The displacements before peeling off and the maximum forces supported are the same. On the contrary, under lateral forces it is recommended to use them.

3. The material of the frame has influenced under lateral forces. The maximum forces supported by the MR fluid are double than when the frame is made of a non-magnetic material. Therefore, it is recommended manufacturing the frame with a magnetic material.
4. The sealing of the gap between the frame and the pole adaptor means an increase of the supported loads around 50 -70 kg when the loads are attractive loads. However, when the loads are lateral loads the sealing means a decrease of the supported loads around 20 - 40 kg. It is recommended to use it.
5. The maximum forces supported by the reference MR fluid MA 1 are much lower than with the improved MR fluids, as it was expected. The effect is bigger under attractive forces (58 kg supported by MA 1 instead of 160 kg supported by MA 240). MA 240 shows a little bit strength under flux density around 80 -100 mT than MA 28, but the viscosity of the latter is lower. Both fluids are suitable for using in the MR fixture.
6. The MR fluid W252 (water based MR fluid) has showed similar strength as the MR fluid MA 240 under attractive and lateral forces. MA 240 support forces a little bit higher, in the range of 25-50 kg.
   The handling of the water-based MR fluid is easier because its viscosity is lower than in an oil-based MR fluid. However, the water-based MR fluid gets thicker very fast. Indeed, after one hour in direct contact with the air its viscosity is much higher. It has been also detected that the MA W252 gets drier and “breaks” into pieces. On the other hand, cleaning the fixture after using the water-based fluid is more difficult as the fluid is stuck on the fixture. The reason could be that the water evaporates very fast.
7. Under attractive forces, the maximum load supported is between 90 and 110 kg, while without the pole adaptor the maximum load supported is between 160 and 180 kg. Under lateral forces, the maximum load supported is between100 and 125 kg, exactly the same as without it. The pole adaptor has not fulfilled the expectative. No improvements have been detected using it.

On the other hand, the MR fixture has been **tested under real machining conditions**. The *objectives of the experimental tests* are two: 1) to check whether the fixture is able to support the cutting forces and 2) check the behaviour of the MR fluid before, during and after the machining. The machining tests have been done with the plastic seal and with the stainless steel frame. The MR fluid used is MA 240. Both T-profiles have been machined; the shorter and the longer ones.

Figure 38. Photos taken during the machining of the horizontal side of the shorter profile

During the experimental and machining tests, people from SPASA, FATRONIK and AIBE have evaluated the behaviour of the fixture before, during and after the machining. The conclusions they obtained are explained next:

Before machining

- What is the opinion of SPASA about handling the MR fluid before machining?

The viscosity of the MR fluid is too high. For an industrial use, the pouring of the MR fluid should be done by means of a pump. Pouring directly the MR fluid from a container takes too much time. The quantity of MR fluid to be poured should be known in advance.

During machining

- Is this fixture suitable to support the machining forces?

The fixture was able to support the cutting forces applied during the experimental tests apart from the machining of the horizontal side of the shorter profile with an axial depth of 2 mm.

- How is the behaviour of the MR fluid during machining?

During machining a lot of titanium shavings are generated. If there is MR fluid in the upper side of the fixture the shavings get in touch with the MR fluid. If the MR fluid is nearly fluidic there, it gets mixed with the shavings and that implies dirtiness and difficulty of eliminating the shavings.

Therefore, it is important, on one hand, to know the quantity of MR fluid to be poured. MR fluid should not overflow the fixture but should fill the lateral space between the T-profile and the frame in order to allow a magnetic sealing in this area. On the hand, an uniform and high flux density is required to solidify as much as possible the MR fluid and thus, avoiding shavings get mixed with it.

Finally, it has been checked that the lubricant has not mixed with the MR fluid. With the magnetic field ON the lubricant is cleaned by means of compressed air.

After machining

- Is it easy to clean the shavings and MR fluid after machining?

As it has been appointed before, if there is MR fluid in the upper side of the fixture and the MR fluid is fluidic the shavings get mixed with the MR fluid and it is difficult to eliminate them. In any cutting process, the shavings are collected by a conveyor and recycled. If the shavings are mixed with MR Fluid, they must be cleaned before recycled them. No problems happen when the machine tool gets in contact with the MR fluid.

Techno-economical validation of the MR fixture

Finally, a techno-economical validation of the MR fixture has been performed.

It has been checked during the MAFFIX project that the **MR tooling** is a **flexible and reconfigurable tooling suitable for long parts without reference faces**. It is defined as flexible and reconfigurable as it can be easily adapted to different profile's lengths and sections and it is able to fix parts without reference faces as the MR fluid adapts to the outer shape of each profile. The MR tooling will allow performing operation #2 first and then, following with operations 1 and 3 that could be done in actually available tooling # 3 with small modifications and thus, **reducing in one unit the number of different toolings needed**. Despite this change could seem no significant, it is a very important step since due to the non-homogeneity of the extruded profiles used for producing the parts (in shape and surface finishing), operation 1 is required and cannot be done later together with operation 3.

Regarding the **uploading time**, the **time needed to pour the MR fluid and fix the T-profile is around 5 minutes whilst 20 min are needed to fix the profile with the conventional fixture.**

Regarding its behaviour **under real machining efforts**, it can be concluded from the machining tests performed that the **MR fixture is able to support the cutting forces applied**.

From the **economical point of view**, the new MR fixture means a **great cost reduction** in the manufacturing of the final part because of mainly 2 reasons: i) the fact that **1 tooling less is needed** to manufacture the final part and ii) the **uploading time** has been **reduced from 80 min to 45 min**. Currently 4 uploading are needed and each of them takes around 20 min whilst using the new MR fixture, 3 uploading are needed and one of them only takes 5 min instead of 20 min.

The cost of the MR fixture prototype has been around 30.000€. This cost is acceptable to SPASA. However, it has to remind that the prototype built is only 1.400 mm when the real T-profiles are up to 2.875 mm. The prototype manufactured has allowed validating the concept of using MR fluids to hold long aeronautical parts without referenced sides. After MAFFIX project an important work for driving from the actually available conceptual and technological prototype to a real industrial solution is needed.

2.6 Deliverables and milestones during the reporting period

In the next tables (Table 6 and Table 7) it is shown the list of deliverables and milestones during the reporting period (M0-M26)

Del. no.	Deliverable name	WP no.	Lead participant	Date due	Actual delivery date
D1	Health and safety issues related to magnetorheological fluids.	0	FHG-ISC	SEPT 07	Delivered
D2	End-user requirements for the MR fixture	1	SPASA	JANUARY 07	Delivered
D3	MR fixture system concepts and associated operational procedures	3	AIBE	APRIL 07	Delivered
D4	Characteristics and performances of the MR fluids synthesized	2	FHG-ISC	SEP 07	Delivered
D5	Plan for using and disseminating knowledge (first version)	0	FATRONIK	SEP 07	Delivered
D6	MR fixture structures and magnetic circuits	3	ZIP	APRIL 08	Delivered
D7	Description of properties and synthesis process of the final MR fluid	4	FHG-ISC	OCT 08	Delivered
D8	Testing and evaluation of the MR fixture performances	5	ROEMHELD	OCT 08	Delivered
D9	Plan for using and disseminating knowledge (final version)	0	FATRONIK	OCT 08	Delivered

Table 6. Deliverables during the reporting period (M0-M26)

Mil. no.	Milestone name	WP no.	Lead participant	Date due	Actual delivery date
M1	Selection of candidate workholding processes for introduction of the MR fixture	1	SPASA	November 2006	30^{th} November 2006
M2	Selection of the best concepts for the MR fixture and for their workholding methods	3	AIBE	April 2007	30^{th} April 2007
M3	Mid-term assessment meeting with the Commission representative	0	FATRONIK	September 2007	26-27^{th} September 2007

Table 7. Milestones during the reporting period (M0-M26)

3 CONSORTIUM MANAGEMENT

3.1 General aspects

The project was officially launched with the celebration of the kick-off meeting, held in San Sebastián (Spain) on 12-13th September 2006. In this meeting the main management tools and internal working procedures for the project were agreed and established. Those points have been compiled and detailed in the Consortium Agreement (CA) signed by all partners just after the kick-off meeting. The CA aims at developing individual aspects that are specific for the project and that are not regulated in the EC contract, or regulated in a generic way, such as property of results, management, access right, confidentiality,… All the partners sent amendments and contributions and Fatronik composed a document that includes all the changes proposed by the partners.

The coordination of the project has been divided by Fatronik, project Coordinator, into two major fields: the technical and the administrative one. For each of these divisions Fatronik has provided a permanent responsible: Ms. Mariola Rodríguez, Technical Coordinator, and Mr. José de la Rosa, Administrative Coordinator.

The project has passed the mid-term review with positive comments and it has been punctuated as “good to excellent project (the project has fully achieved its objectives and technical goals for the period and has even exceeded expectations)”. The mid-term meeting was held in Miranda de Ebro (Spain) on 26-27Th September.

The co-operation between partners is being good. All the partners are contributing to the project as it was planned. The resources already used by partners are according to the initial planning.

Regarding the budget, the EC has accepted (12 November 2007) a change in the budget of Röemheld and Ima-Metav. This change does not affect the total budget of the project and does not mean transfer of activity between partners. Röemheld and Ima-Metav will perform the same activities arranged in the technical annex. The changes in budget comes from the differences in direct personnel cost. The real Ima-Metav cost per PM is about 969 €/PM while the estimated one was 4.050 €/PM. The real Röemheld cost per PM is about 9.587 €/PM while the estimated one was 5.400 €/PM. This change means that Röemheld will justify 93.000 € more than estimated and Ima-Metav will justify 93.000 € less than estimated.

A detailed plan for using and disseminating of knowledge (PUDK) was presented with the mid-term report (D5), which present in an appropriate way all necessary aspects i.e.

exploitable knowledge and dissemination methods. The final version of the PUDK has been composed (D9) and submitted with this report. The IPR issues are properly addressed. MAFFIX partners have already started the procedure to apply for a patent of the results of the project.

The final meeting of the project was held in SPASA on 22-23th July 2008. During the final meeting partners decided to ask for an enlargement of 2 months in order to develop and implement improvements in the demonstrator. The Project Officer accepted to enlarge the project until 31st October 2008.

Partners have fulfilled all the objectives defined in the proposal as it has been explained during section 2. All the deliverables and milestones have been achieved.

3.2 Communication between partners

The internal exchange of information between the partners of the Consortium has been carried out basically by e-mail. The communication between all the partners of the Consortium is good and agile, as it can be inferred from the amount of e-mails exchanged in the reporting period.

On the other hand, a web site has been created (http://maffix.fatronik.com) where all the information related to the project is compiled and may be accessed by all the partners. This web site is updated and completed regularly with the new documents or changes by the project coordinator. The web site is divided in two main areas:

- The *public access section*, where generic and non-confidential information about the project is compiled. Aspects such as the main objectives and outcomes foreseen for the project, information about the partnership involved in the project, as well as publications and non-confidential technical issues are included.

- The *members only* section, protected by password, that contains confidential information about the project only accessible by the members of the Consortia. The information included is: *Meetings*, including agenda, presentations and minutes of every meeting held in the project; *Contract Documents*, with all the contractual documents available both external (with the Commission) and internal to the Consortium (such as the Consortium Agreement); *Templates; Deliverables*; *Internal Documents*, where all the technical documents produced in every task are available; *Project Monitoring*, where every partner may find all the internal reports and cost statements already sent by him; *Partners Contacts*, with all the contacts updated; and *Exploitation and Dissemination* where the Plan for Using and Disseminating the knowledge can be found.

3.3 Meetings

During this period the following meetings have taken place:

DATE/PLACE	PARTNERS INVOLVED	GOALS
12-13/09/2006: FATRONIK (San Sebastian, Spain)	All MAFFIX partners	Project Kick-off
23-24/01/2007: ISC (Würzburg, Germany)	All MAFFIX partners	Technical Meeting
26-27/09/2007: SPASA (Miranda de Ebro, Spain)	All MAFFIX partners	Project mid-term meeting
17/01/2008: ROEMHELD (Laubach, Germany)	ROEMHELD, FRAUNHOFER-ISC, ZIP & FATRONIK	Technical Meeting focused on MR fluids and magnetic plates
04/02/2008: SPASA (Miranda de Ebro, Spain)	SPASA, AIBE & FATRONIK	Technical Meeting focused on the design of the fixture for the T-profile
22-23/07/2008: SPASA (Miranda de Ebro, Spain)	All MAFFIX partners	Final meeting

3.4 Other issues

MAFFIX is a CRAFT type project whose consortia are composed by 8 members. Three of them are RTD partners (FATRONIK, FRAUNHOFER-ISC and ZIP) and other 5 are industrial partners (SPASA, HIGHFTECH ENGINEERING, ROEMHELD, AIBE and IMA-METAV).

In the project, consortia have worked 215,4 PM. 60% of the work has been done by industrial partners and 40% of the work by RTD partners. The RTD partners are focusing their work on the following issues:

- Development of the MR fluid for the fixture system; near-application testing of MR fluids and final improvements and up-scaling of the MR fluid synthesis. Fraunhofer-ISC is developing this work.
- Design the magnetic circuits to generate the magnetic flux density needed; design the mechanism to switch ON and OFF the magnetic field; integration of the magnetic circuits in the complete fixture. ZIP is developing this work

- Conceptual design of the fixture, modeling and simulation activities to predict the behaviour of the new fixtures; integration of basic technologies developed in the field of MR fluids and magnetic circuits; guarantee the fulfillment of the industrial requirements. Fatronik has developed this work.
- Manufacturing and testing of the prototype of the MAFFIX project. Performing static and machining tests. Techno-economical validation of the prototype. Fatronik has developed this work.
- Definition of improvements after preliminary tests. Design, manufacturing and implementation of the improvements in the MAFFIX prototype. ZIP and Fatronik have developed this work.

The INDUSTRIAL partners are focusing their work on the following issues:

- Identifications of parts to be fixed by a fixture based on MR fluids; definition of requirements; evaluation and final selection of the conceptual designs proposed by RTD partners; tests of final designed and manufactured fixture prototypes. SPASA, HIGHFTECH ENGINEERING and IMA-METAV are developing this work.
- Evaluation and final selection of the conceptual designs proposed by RTD partners; development of fixture concepts and detail design of the fixtures to be manufactured in the project; improvements implementation in the fixture; tecno-economical comparison with currently used fixturing systems. ROEMHELD and AIBE are developing this work.
- Manufacturing and testing of the prototype of the MAFFIX project. Performing static and machining tests. Techno-economical validation of the prototype. AIBE, ROEMHELD, SPASA, IMA-METAV and HIGHFTECH have developed this work.
- Design, manufacturing and implementation of the improvements in the MAFFIX prototype. ROEHMHELD and AIBE have developed this work.

Next, it is detailed the role of each partner in each WP.

	COMPANY	Country	Type of participant	Main activity	Role of in project
INDUSTRIAL PARTNERS	**SPASA**	Spain	End-user	Precise machining of aeronautical metallic parts	**WP1**: identification of fixtures most suitable for being tacked with MRF based fixture **WP3**: Evaluate the system concepts, selection of the best ones and monitor the design of the fixture. **WP5**: First tests of the fixture. Problem detection. Final tests and evaluation of achieved performances
	HIGHFTECH	Italy	End-user	Manufacture of prototypes and complex parts for the space industry	**WP1**: identification of fixtures most suitable for being tacked with MRF based fixture **WP3**: Evaluate the system concepts, selection of the best ones and monitor the design of the fixture. **WP5**: First tests of the fixture. Problem detection. Final tests and evaluation of achieved performances
	INA-METAV	Rumania	End-user	Design and production of parts for the aeronautical sector	**WP1**: identification of fixtures most suitable for being tacked with MRF based fixture **WP3**: Evaluate the system concepts, selection of the best ones and monitor the design of the fixture. **WP5**: First tests of the fixture. Problem detection. Final tests and evaluation of achieved performances
	AIBE	Spain	Fixture manufacturer	Design and production of fixtures for manufacturing and verification	**WP1**: identification of fixtures most suitable for being tacked with MRF based fixture **WP3**: Develop system concepts and detail design of the fixture **WP5**: Improvement implementation in the fixture. Techno-economical comparison with currently used fixturing systems
	ROEMHELD	Germany	Fixture manufacturer	Hydraulic power workholding for metal-cutting production engineering	**WP1**: identification of fixtures most suitable for being tacked with MRF based fixture **WP3**: Develop system concepts, detail design and manufacturing of a fixture **WP5**: Improvement implementation in the fixture. Techno-economical comparison with currently used fixturing systems

	COMPANY	Country	Type of participant	Main activity	Role of in project
RTD PARTNERS	**FATRONIK**	Spain	RTD	Wide experience in integrated design of artefacts (machines, automation and production systems, systems for renewable energy generation..)	**WP0**: Global coordination and project management **WP3**: Develop system concepts, detail design and manufacturing of fixture mechanical parts and auxiliary devices **WP5**: Monitoring of first tests of the fixture. Problem detection and analysis. Proposals for improvements
	ZIP	Germany	RTD	Wide experience in electrically controllable fluids (ERF/MRF)	**WP3** Develop system concepts, detail design and manufacturing of fixture electrical parts and magnetic circuits. **WP5**: Monitoring of first tests of the fixture. Problem detection and analysis.
	ISC	Germany	RTD	Wide experience in designing and producing MRF	**WP2** development, synthesis and characterisation of special MRF formulations **WP4**: improvement of MRF, investigation of production of batches **WP5**: Monitoring of first tests of the fixture. Problem detection and analysis.