Development of a Nuclear Mixing Process for High Performance Cementation – 15064

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ABSTRACT

In the CEA[1] Project "Cementation of LLW/ILW[2] Slurry" EIRICH[3] and CEA developed together a high performance mixing process matching the French security regulations for nuclear facilities. Since 2010 mixing tests had been carried out by CEA to develop and verify a new cementation process. In 2012 EIRICH started the development of the mixing equipment for the cementation plant together with CEA. This new cementation plant will be put into operation in 2016 at the CEA site in Marcoule.

INTRODUCTION

The objective of the new cementation process is to treat slurries produced by the insolubilization of radioelements in wastewaters (around 600 m^3/y). In 2016 the CEA Marcoule center will start a new facility to immobilize sludges in cement, replacing its old bitumen unit. 10 to 15 campaigns per year will be produced, each time around 10 drums of 380 liters.

The main advantages by usage of cement in the new LLW/ILW treatment are: the mineral matrix has on the one hand no thermal reactivity and on the other hand a good mid-term stability up to 300 years. The final product respects the requirements of ANDRA[4].

Regarding the new mixing technology the benefit is to treat highly viscous mixtures. Due to the higher homogeneity of the mixed material also cement defects and crack formations are reduced as required by ANDRA. Hereby also the compressive strength can be increased.

The objective of the joint development between EIRICH and CEA is a high performance mixing process which first optimizes the cementation by a higher quality and life-time of the disposal drums but also fulfills the nuclear environment criteria e.g. automation, redundancy, disassembly and maintenance operations in confined space.

During the development CEA contributes its know-how of the nuclear industry especially the requirements which are necessary to fulfil the French security regulations for nuclear facilities. EIRICH contributes its know-how of the intensive mixing technology esp. the long-time experiences in many industries with a broad variety of process materials. Both experiences enable an optimized waste preparation for the cementation in a nuclear facility.

[1] Commissariat à l'énergie atomique et aux énergies alternatives / French Atomic Energy Commission
[2] Low Level Waste / Intermediate Level Waste
[3] Maschinenfabrik Gustav Eirich GmbH & Co KG
[4] Agence nationale pour la gestion des déchets radioactifs / French National Radioactive Waste Management Agency

PRINCPLE AND ADVANTAGES OF THE INTENSIVE MIXING TECHNOLOGY

The intensive mixing technology has three main characteristics compared to other mixing technologies which lead to several advantages for the produced process material:

- The mixing process is performed by a fast rotation of the mixing tool to achieve the required mixing intensity and a high energy input.
- The rotation of the mixing pan ensures a continuous feed of process material to the excentric positioned mixing tool.
- The bottom and wall scrapers generate an additional agitation of the material flow, they prevent a material built-up on the wall and bottom of the mixing pan and they accelerate the material discharging.

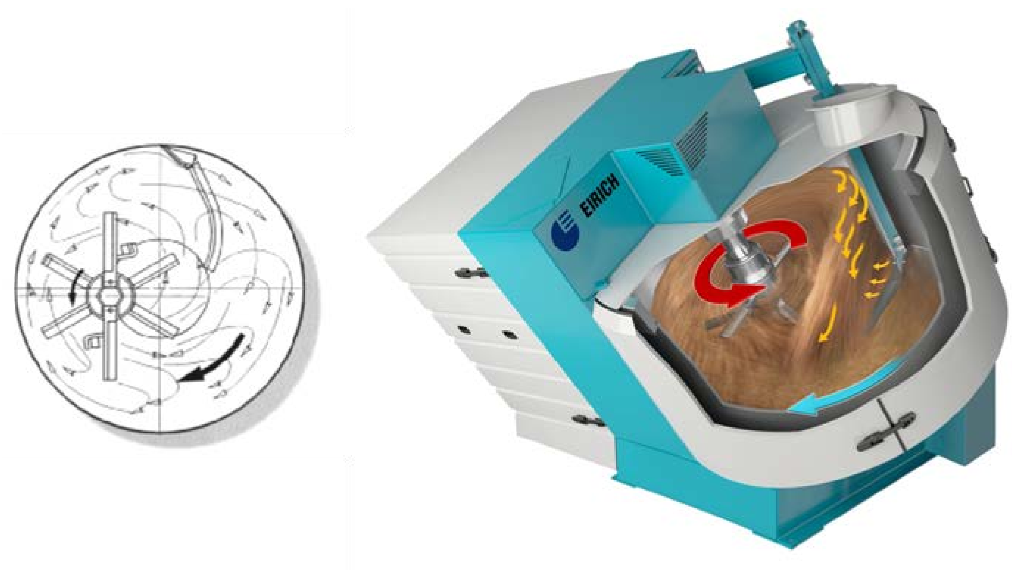

FIGURE 1. Principle of the intensive mixing technology

Therefore the intensive mixing technology has several advantages:

- Higher quality of the mixture especially the homogeneity
- Lower amount of reject material
- Reduced mixing times due to intensive mixing
- Lower amount of additives by a better utilization of raw materials
- Reduction of energy consumption

DEVELOPMENT OF THE HIGH PERFORMANCE MIXING PROCESS

On the basis of the intensive mixing technology CEA has been developing and verifying a new cementation process with a demonstration platform performing tests with non-radioactive slurries. This platform size is one fourth of the production unit and is representative of the future full scale unit.

To immobilize its slurries, the CEA has previously defined the cement based formulation (CEM I, plus a non alkali-reactive silica sand with a sand/cement ratio of 0.67) and a rate of incorporating of dry slurry around 8%. A plasticizer is also added. This cement formulation was defined to match the main following criteria:

- Homogeneity of the mixed materials
- Minimization of the internal temperature
- No bleed water at 24 hours
- Mechanical strength under compression greater than 8 MPa at 90 days.

Thanks to its platform with an EIRICH mixer allowing batches of 150 l, full scale packages (380 liters drum) were produced with a series of 4 mixes.

The results show that the maximum temperature is 79°C at 47 hours at the center of the package. There is no bleed at 24 hours and the density of the fresh mortar is 1.83 which is in compliance with expected results. The mechanical strengths are always above 20 MPa. Finally, the observations of the package reveal no fault. On a microscopic scale, the structure is similar for the entire container. The cement-based matrix includes sludge nodules of about 150 micrometers.

The other main advantages with tests at a platform scale are to set the durations of each step to be performed to obtain a compliant package. Table 1 shows the chronogram of the complete process.

TABLE 1. Operation steps and durations of the new mixing process for high performance cementation

step	operation	duration (min.)
1	Dosing cement	5
2	Dosing sand	5
3	Dry mixing	3
4	dosing sludge and plasticizer	15
5	Wet mixing	5
6	Discharging	5
7	Transfer of disposal drum	5
8	Cleaning	3
Total mixing cycle		**46**

DEVELOPMENT OF MIXING EQUIPMENT CONSIDERING THE REQUIREMENTS OF THE NUCLEAR INDUSTRY

In the following some functions are shown which are most important for the nuclear industry and which have been developed for this kind of application in the CEA project. The whole mixer is a new development on basis of the nuclear requirements.

The capacity of the mixer has been set to 380 liters corresponding to the size of a nuclear disposal drum. This corresponds to 650 kilograms considering the bulk density of the process material. The whole mixer is made of corrosion resistant stainless steel integrated in a fully automated plant by PLC control system. It meets the French security regulations for nuclear plants including all controls.

The leak tightness of the mixer is one important requirement. Therefore a one piece mixing pan without door has been developed. The mixing principle requires a rotating mixing pan and a seal between the top edge of the mixing pan and the upper cover. Leakage of mixed material through this seal has to be reduced to a minimum. The developed concept is a combination of a double lip seal configuration and additionally an inward directed airflow through the seal. This airflow is generated by suction of air through the mixing pan cover to generate a low air pressure inside the mixing pan and hereupon an inward directed air flow through the sealing. For a monitoring of the leak tightness three inspection windows have been applied to the low pressure casing. These have integrated fixtures to position lead curtains for radiation protection.

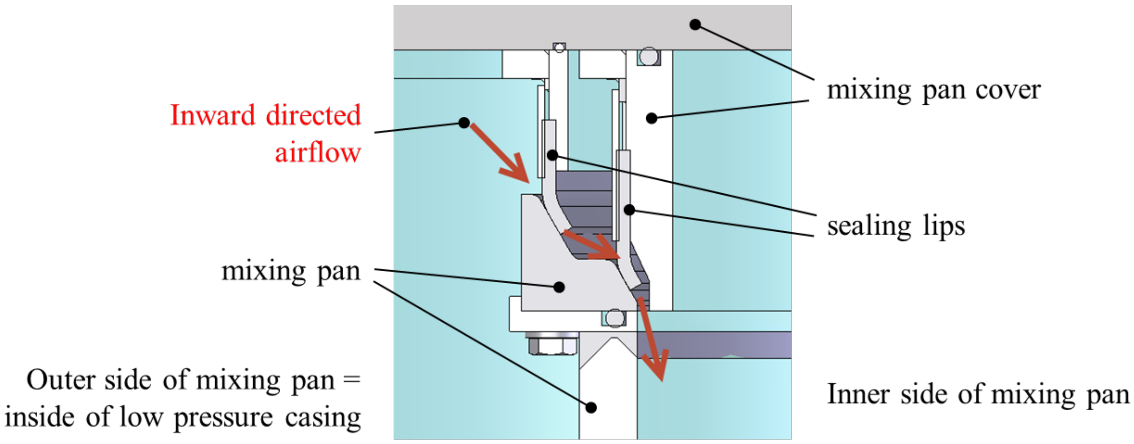

FIGURE 2. Double lip sealing assembled on the mixing pan cover

For a complete emptying of process material and cleaning fluid a cone-shaped bottom has been applied to the mixing pan. During the discharge period on the one hand the wall and bottom scraper removes the mixed material from the interior surfaces to reduce remaining process material. And on the other hand the second important function is the acceleration of the emptying process with the bottom scraper conveying the mixed material directly into the discharge gate. To control the material flow through the discharge gate of the mixing pan an inclination sensor has been installed. This enables the operator via the control system to position the discharge gate for an appropriate material flow through the discharge gate into the disposal drum.

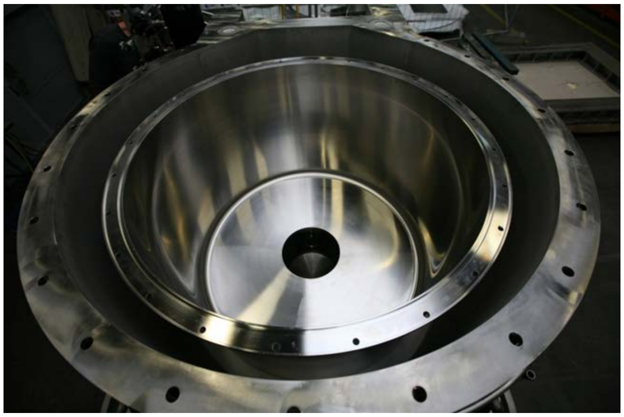

FIGURE 3. Stainless steel mixing pan with cone-shaped bottom and opened discharge gate - encircled by the low pressure casing

For redundancy the discharge gate is equipped with two hydraulic cylinders. The actuation of the cylinders can be triggered separately or simultaneously. If one hydraulic cylinder fails the mixer can be emptied by the other cylinder.

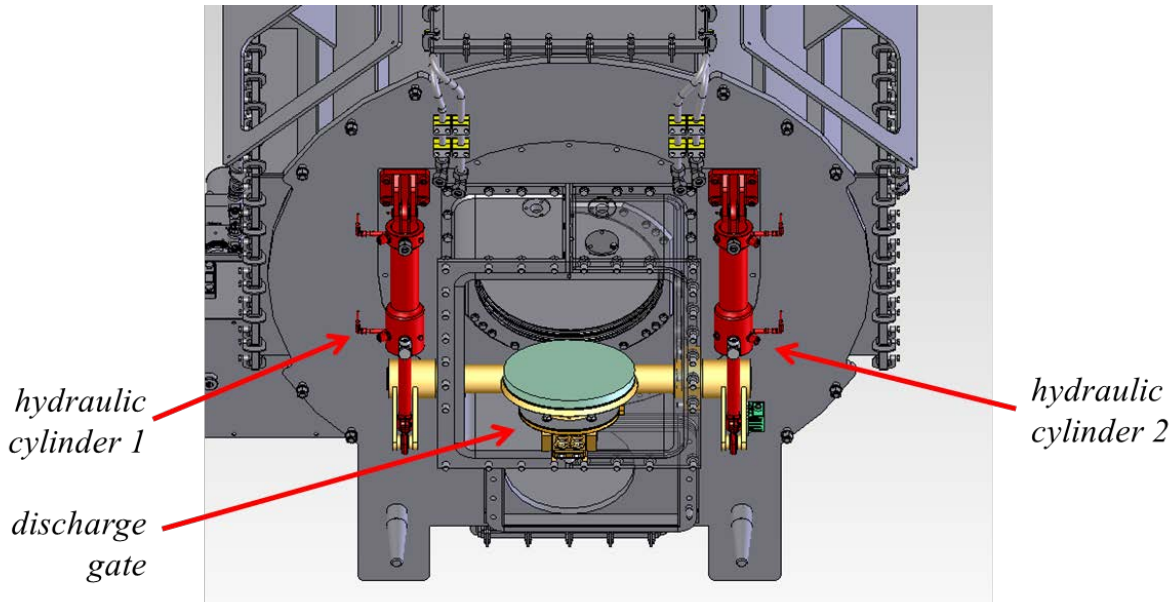

FIGURE 4. Two redundant hydraulic cylinders with inclination sensor for control of the material flow through the discharge gate

For the reliable function of the mixer throughout its lifetime an efficient cleaning system is essential. This implies an entire cleaning of components which are in contact with process material. Therefore two rotational cleaning nozzles have been installed in the upper cover of the mixer and twelve cleaning nozzles in the outlet of the mixer. The developed cleaning system operates at 10 MPa (100 bars) using 180 liters of water for each cleaning cycle. Depending on the number of subsequent batches the mixer has to be cleaned regularly to prevent a hardening of the cement based material inside the mixer.

FIGURE 5. Rotational cleaning nozzle installed in the upper cover of the mixer

With an additional weighing system underneath the mixer two functions can be realized. On the one hand the dosing of the material can be monitored to avoid an overfilling of the mixer. This is a redundant safety function as the feeding of the materials is controlled primarily by the dosing components itself. The second advantage of the weighing system underneath the mixer is to monitor in the case of a failure the possibility of remaining process material after discharging the mixer.

An important functionality for the nuclear industry is the maintenance aspect. The mixer is especially developed to be disassembled by two separation sections for easy access to the components. For emergency cases the mixer can be separated from the ground frame to be disposed completely closed with the containing process material. In case of a failure at the drives (rotor tool, mixing pan) or the cleaning nozzles these components can be disassembled in a completely hermetically sealed environment inside protection bags.

CONCLUSION

The characteristics of the intensive mixing technology (high speed mixing tool, rotating mixing pan, bottom and wall scrapers) result in several advantages for mixing processes which can be used in the nuclear industry.

The tests on the platform make it possible to validate the results obtained in the laboratory on the cement matrix. On the basis of this mixing technology a new cementation process was developed with a final product meeting the requirements of ANDRA.

On this basis EIRICH developed a new mixer matching the French security regulations for nuclear facilities. The development of the “Nuclear Mixer” resulted in the following features:

- Automated operation
- High leak-tightness
- Complete emptying of process material
- Efficient cleaning system
- Inspection windows
- Hermetically sealed dosing of process materials
- Position monitoring of the discharge gate
- Redundant components, e.g. hydraulic cylinders
- Integrated weighing system
- Separation sections for disassembly and maintenance operations in a confined space
- Disposal of the complete mixer in emergency case
- Robust and safe hydraulic system

The developed mixing equipment is currently in production and assembly. Results about the first tests, delivery and commissioning of the mixer will be shown in the oral presentation as far as possible.