Kerntechnik 2022 – Young Scientists Workshop

Germany, Leipzig – 2022, June 21-22

Development of a universally applicable internal pipe separation system for hard-to-reach (contaminated) areas (RoTre)

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1 Introduction

During the operation and dismantling of nuclear facilities, individual pipelines must always be removed due to leaks because of their maximum service life or the dismantling of the plant. In practice, this activity, which appears simple, at first glance, is associated with a variety of challenges due to confined space or the routing of pipelines through walls, despite various solutions available on the market. The range of possible cutting methods extends from the simplest pipe cutters, such as shear and roller pipe cutters, to water jet and water-abrasive cutting systems, to complex cutting systems with conventional cutting tools (saws/mills) that are developed specifically for special applications. Often, the actual dismantling or replacement of the pipe or a bundle of pipes must be preceded by a complex uncovering process in order to be able to separate and subsequently remove manageable pieces. The pipe is usually cut from the outside. The accessibility of the pipe to be cut, the means of transport for removal, the materials used and the pipe parameters, such as diameter and wall thickness, and, in the case of large pipes, the equipment for fixing the pipes, are the decisive selection criteria for the cutting process.

A technique for separating a wide variety of pipelines from the inside of the pipe would significantly reduce the effort involved. In addition to the fact that there is no need to expose the pipeline to be dismantled, the steps of cutting and removal in particular can be combined. Likewise, the combination of cleaning the pipe with a subsequent cutting process is conceivable. So far, such a process for universal cutting of the pipeline from the inside of the pipe is not available on the market. The processes currently available are intended for special applications and have disadvantages, for example with regard to the applicable pipe diameters or wall thicknesses.

In particular, the decommissioning or dismantling of nuclear facilities represents a major challenge in Germany as well as internationally, which the nuclear energy countries are increasingly having to face. During the dismantling of the plants, pipe systems are made up of different materials with diameters ranging between 100 and 500mm have to be dismantled on a large scale [1]. It should be noted that when dismantling is carried out, individual piping systems must remain functional, while others are to be removed.

The joint project between the Karlsruhe Institute of Technology (KIT), Siempelkamp NIS Ingenieursgesellschaft mbH and RWE Nuclear GmbH, funded under the FORKA - Research for the Dismantling of Nuclear Facilities - program, aims to develop an innovative and more competitive internal pipe cutting device with a wide range of applications in terms of pipe diameter, wall thickness and material. In addition to the pure cutting and transporting of the pipes, it is also planned to develop a possibility for a preceding cleaning process. Any chips or other residual materials are to be continuously extracted. In addition to the dismantling of pipelines that are difficult to access (for example, pipelines that are embedded in concrete and cannot be bored over their full length), dismantling should be possible both in air and under water. For flexible use, the operation as well as the insertion into the pipe to be separated shall be possible manually or remotely. The system is designed in such a way that it can be decontaminated after use so that it can be used universally. Due to the high flexibility and the universal applicability, many working hours for the development and construction of special individual solutions can be saved.

2 State of the art

There is no internal pipe cutting system on the market that allows universal use on a wide range of pipe diameters, wall thicknesses and materials, as well as their removal and, if necessary, prior cleaning. Consequently, no system is currently available that can be used universally in a wide range of different highly demanding applications. On the contrary, existing pipe separation systems have significant drawbacks. Among the most important weaknesses are:

- No mobile use possible
- Pipes are mainly cut from the outside, the tool must be attached to the pipe from the outside
- Long heavy segments often have to be pulled when overdrilling, which means that the lifting tool has to be dimensioned accordingly
- Chips are produced during the cutting process (dust, chips, etc.)
- No integrated drive and holding system
- No combination of cutting and cleaning as well as removal of the cut tubes
- High set-up and assembly times or time-consuming preparatory work in the blasting field for special requirements on the cut quality, e.g. for the production of qualified closures
- Cutting systems for cutting from the inside are specially developed for a specific application or tube diameter

The devices currently available on the market are waterjet abrasive cutting systems, external pipe cutters as well as internal pipe cutters, which, however, exhibit the weaknesses listed above [2, 3]. A closer examination of the individual systems clearly reveals the shortcomings of the devices. For example, if we look at the diameter range of the devices available in the market, they are either designed for individual cases or are only suitable for small or large diameters. With the universal pipe cutter to be developed, this deficit could be eliminated, since a diameter range of 100 to 500mm is targeted, enabling flexible application for a wide range of pipes. Another disadvantage of the available systems is their limited use under water, because apart from the waterjet abrasive cutting system, the other systems cannot be used under water or their use is only made possible under certain boundary conditions. Due to the fact that the available equipment is not universal and mobile, the range of application and use of these systems is further limited, which highlights the need for a universal internal pipe cutting system. Pipe cutters also have the further disadvantage that accessibility around the entire pipe exterior must be guaranteed. These devices can therefore not be used in confined spaces. Unless pipe encapsulation is provided for the devices established to date, they release emissions during the cutting process due to the escape of water, abrasive and chips.

3 Rough concept of the planned internal pipe separator

The Siempelkamp NIS is based on a central support tube for the development of the internal pipe separator, which can be compared in figure 1. Round plates are attached to this support tube, which contain the bearings for the drive rods as well as mounting options for the clamping mechanism. The clamping mechanism consists of three radially arranged rods with clamping claws, which are driven synchronously via threaded spindles. This ensures centering and a wide range of applications for different pipe diameters.

In the machine head, a gearbox provides the conversion of three incoming shaft drives to speed, feed and infeed. The machine head is mounted on the front retaining plate and coupled with the drive linkage. A swivel arm with mold mounting is provided on the machine head itself, with which the infeed takes place. In this way, the planned internal pipe cutter can cover different pipe diameters.

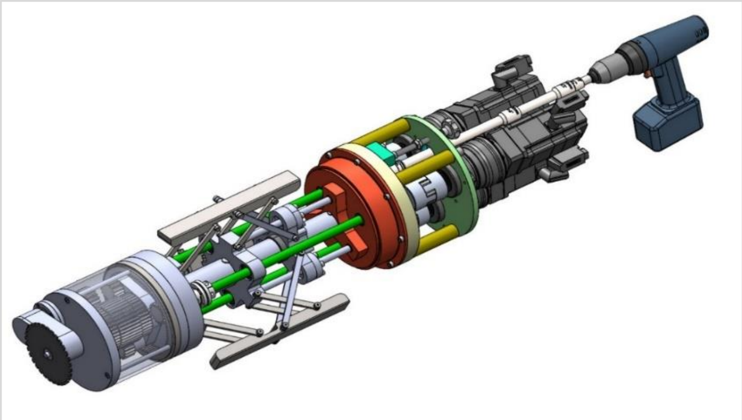

Fig. 1: Schematic rough concept of the planned separation device, which is currently being assembled

The drive unit with the motors is adapted to the rear retaining plate and the drive for the clamping mechanism is realized. Since the drives exceed the installation space for smaller diameters, they are provided outside the pipe to be cut, see figure 2. Based on the current development, a mobile use of the internal pipe cutter for different pipe diameters is possible. Currently, the demonstrator of the internal pipe separator is being assembled. After the first successful tests of the prototype, it will be optimized and further planned functions (extraction, shearing, removal) will be considered at a later stage.

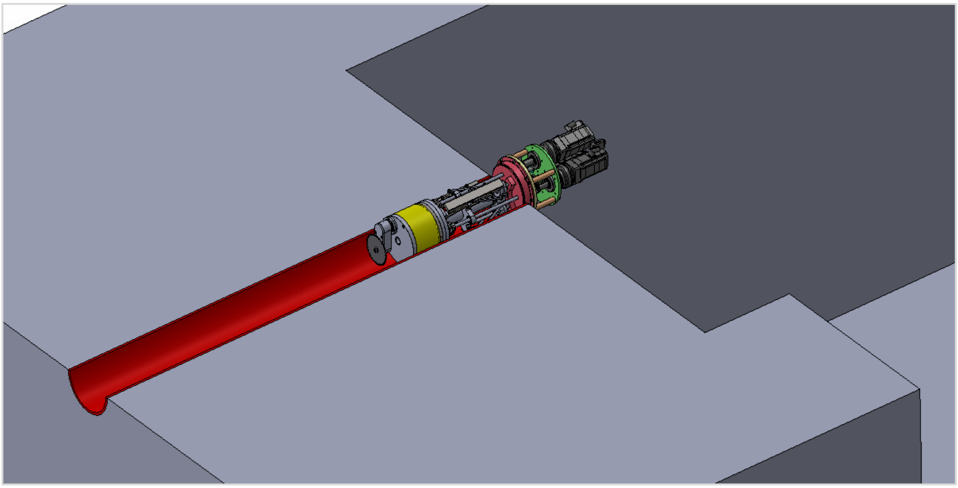

Fig. 2: Outlined operation of the planned separation device

4 Test series

With the planned internal pipe separator, the pipes are to be separated from the inside either by milling, sawing or grinding. The reason for this is that these separation processes are frequently used in practice whit processing (contaminated) pipes. At the Institute for Technology and Management in Construction (TMB) of the Karlsruhe Institute of Technology (KIT), a test rig was developed to investigate which cutting process is best suited for which parameters (speed, feed rate, etc.). This test rig allows a large number of test variations of different specimen, tool setups and boundary conditions. The following is a description of the test rig, including the sensors used.

Fig. 3: Test stand for internal pipe separation at KIT-TMB

The specially developed and constructed test stand in the KIT-TMB test hall, which can be compared in figure 3, is intended to enable various tubes in the diameter range from 100 to 500 mm to be cut from the inside using different cutting tools.

The test specimens (tubes) are driven by a motor at a maximum speed of 0.5 rpm during the test. For this purpose, the specimens are attached to a mounting plate at the rear end of the tube by means of bolts, which are connected to a rotating slip ring torque sensor and the motor via a shaft. For stabilization, the test specimens are mounted on rollers. These are attached to metal struts which can be tightened by star screws.

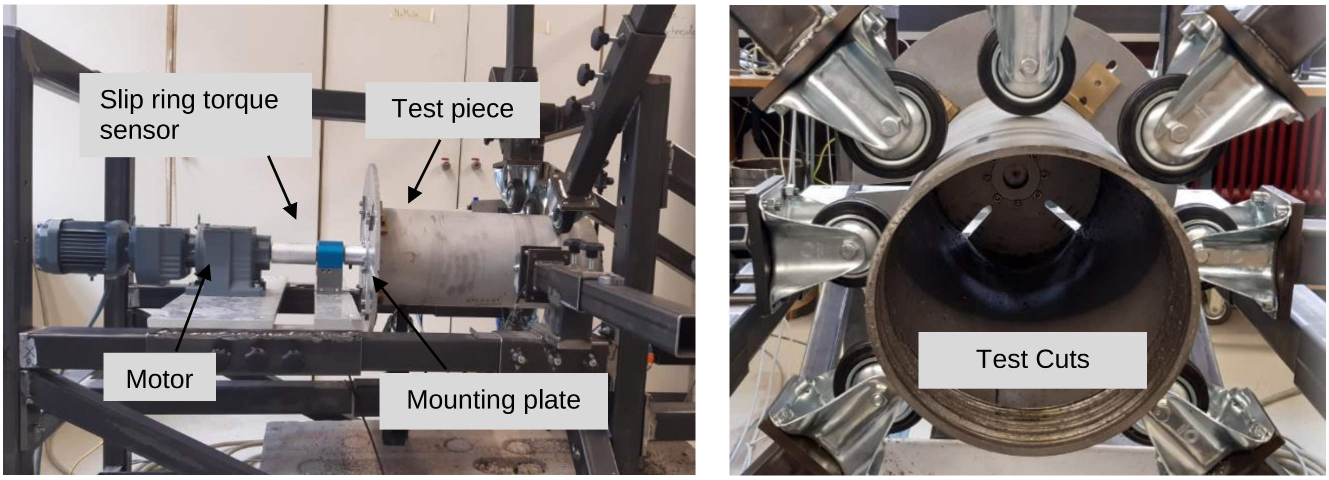

Fig. 4: Detail view of the test piece

The cutting tools can be moved into the specimen via a tool slide. After aligning the correct position of the cutting tool, the tool slide is also attached to the frame structure of the test stand via star screws. As can be seen in figure 5, the tool slide, on which the motor for driving the cutting tools is mounted, is connected to a worm gear and electric motor via a threaded rod. The feed speed is transmitted to the threaded rod via this electric motor and the bevel gear. The feed speed and the feed direction of the tool slide can be set via manual control. The feed rate can be adjusted from 10 to 50 Hz, i.e. from 0.08 to 0.3 mm/min, via a potentiometer.

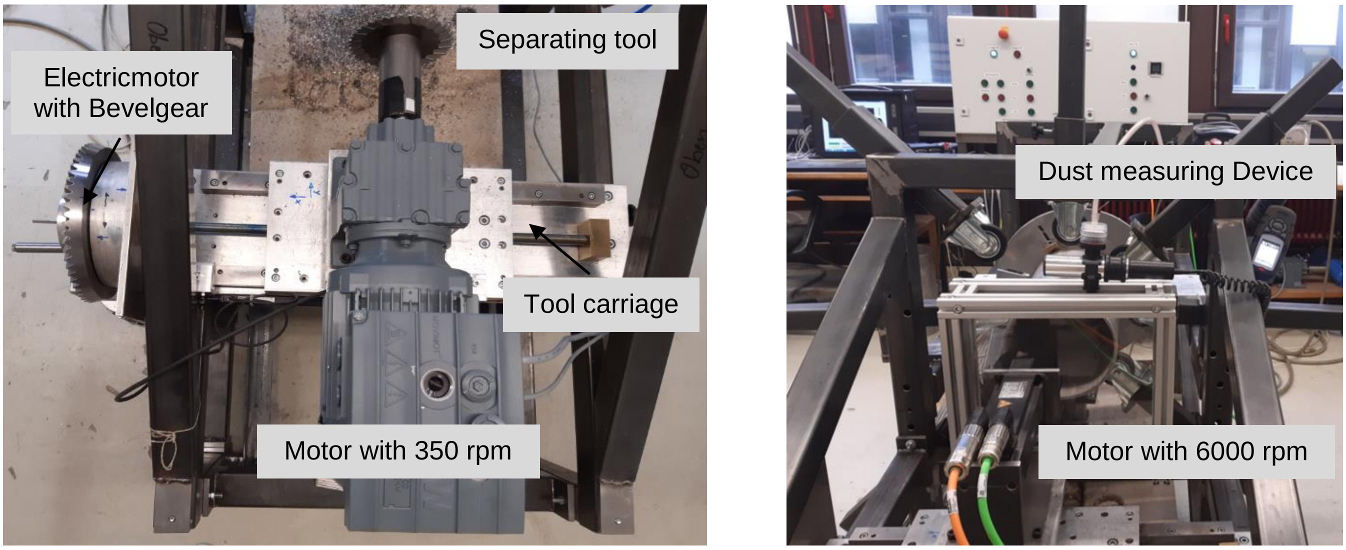

Fig. 5: Gear ratio feed movement and tool slide

A 6-axes force-torque sensor from the company "ME Messtechnik" is mounted under the motor for controlling the cutting tools. The multi-component sensor consists of six independent force sensors, which are equipped with strain gauge full bridges. From the six sensor signals, the forces in three axes of space, as well as the three moments around these three axes, are calculated by a calculation rule [4]. During the cutting process, the temperature developments on the pipe and the cutting tool are also examined. In tests with grinding wheels, dust generation is recorded throughout the hole cutting process. A profile laser scan is used to analyze the quality of the cut and the volume removal [5].

Based on the research carried out on the materials, diameters and wall thicknesses of pipes installed in nuclear power plants, the structures of the test specimens for the 1st test series were developed. According to Wossog et al., steel is used without exception for piping in nuclear plants [6]. The research conducted was to ensure that the development of the test specimens was based on pipes that have been used in nuclear facilities in order to best replicate the practicality of the demonstrator. The planned internal pipe separator should be able to separate both exposed and embedded pipes. Consequently, two different designs of the test specimens will be investigated during the experimental tests. These look as follows:

a. Exposed pipes:

b. Pipes set in concrete:

Currently, the 1st test series is being carried out at KIT-TMB with disc milling discs, saw blades and cutting discs (each in different versions), whereby the feed rate or speed is varied. The test series to date have shown that, in principle, all three cutting methods (in some versions) are suitable for internal tube cutting of stainless steel tubes. The greatest forces during internal tube cutting occurred when using the milling discs or the saw blades. However, with both the milling discs and the saw blade, the cut is very uneven. The cutting discs, on the other hand, generate very small forces and cut the pipe consistently with a clear cut. However, the extraction system integrated into the planned system must be supplemented by a filter system, as the dusts produced are significantly finer than with the two other separation processes. In addition, the temperatures during the cutting process increase.

In the further course of the project, the assembly of the demonstrator must be completed. Subsequently, it must be attached to the test rig of KIT-TMB for further optimizations and in order to verify its suitability for practical use.

5 References

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