Clamping device for the rails and intermediate welding part for orbital friction welding
**Abstract**
This document provides details concerning the clamping tools for the rails and intermediate welding part to be used for orbital friction welding.

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Executive summary

This task focuses on the clamping mechanism for the intermediate component, the sleeves for guiding the rails to be welded, including their clamping systems and the mechanical interface with the FRIEX machinery.

The required clamping tools for intermediate component and the rails to be welded have been designed and are currently being produced.

1 Introduction and background

For the orbital friction welding trials of rails, the equipment available at DENYS (i.e. the FRIEX machine, previously used for rotary friction welding of pipelines) is currently being modified to be able to weld rails according to the new principle developed by Jackweld. A new clamping mechanisms needs to be developed to clamp the rails in the existing clamps.

2 Objectives

- Design of a clamping mechanism for the intermediate weld component,
- Design of a clamping mechanism for the rails to be welded,
- Design of other auxiliary equipment for clamping of the parts.

3 Results

3.1 Introduction

In the past, the FRIEX welding process has been developed for rotary friction welding of pipelines, by a partnership between DENYS, the Belgian Welding Institute and other national partners [1]. In this project, an innovative welding method for fully automatic joining of pipelines was developed. The welding procedure is a variant of the conventional rotary friction welding process. To enable pipelines to be welded using friction welding, a new variant of the conventional process has been developed. The major difference of the new variant with conventional friction welding is that an intermediate solid ring is rotated in between the pipe ends. The axial force in combination with the rotation of the ring generates the required friction and associated heat [2,3,4,5,6].

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[1] : BWI project, funded by IWT Belgium (Agency for Innovation by Science and Technology).
3.2 Large-scale FRIEX test set up

During the development of the FRIEX friction welding process for joining large-diameter pipelines [7,8,9,10,11], a large full-scale test set-up was designed and built for welding pipes up to a diameter of 504 mm (see Figure 2, Figure 3 and Figure 4). The axial friction and forge force is exercised by two large hydraulic cylinders. The maximum available force equals 3000 kN.

The rotation of the welding ring is realised by using 6 hydraulic motors, each connected to a planetary gear system, which are in their turn mounted on a central placed large gear transmission. The welding ring is mounted in the large hollow gear wheel of the gear system, in a rigid clamping device able to transmit the drive power and torque. The maximum rotation speed of the welding ring is 250 rpm. The available effective drive power and torque equals 600 kW and 100.000 Nm respectively.


The rotational speed, the axial friction and forge force and the friction time are the principle variables that are controlled in order to provide the necessary combination of temperature and pressure to form the weld. The heating time is controlled by measuring the axial shortening during the weld cycle. Sufficient material must be consumed to assure adequate heating prior to forging. When the predetermined shortening of the pipes is obtained, the welding ring is decelerated and the axial force is increased to the forge force to create additional shortening.

*Figure 2: Large scale test set up*

*Figure 3: Top view of the test set up*
Figure 4: Back view of the test set up
3.3 Orbital friction welding using the FRIEX equipment

The major difference of the new orbital friction welding process with the FRIEX process is that an intermediate solid disc is placed in between the components (rails) to be welded, and that the motion of the solid disc is orbital and not circular, resulting in a constant tangential speed in any point of the cross section of the interface. The axial force in combination with the movement of the disc generates the required friction and associated heat.

The auxiliary and driving systems previously built during the development of the pipe welding technology “FRIEX” will be adapted for orbital friction welding of rails using an intermediate component, by inserting a specially designed processing core (Figure 6) into the big gear wheel of the DENYS test set-up (Figure 5).

3.4 Dimensions of the intermediate part

The size of the intermediate part has been defined so that 60E1 rail profiles (Figure 7) can be welded using the orbital friction welding process. The rail profile to be welded, together with the forces to be applied onto the intermediate part during the welding operation, define its dimensions.
3.5 Design of the clamping mechanism for the intermediate weld component

The intermediate component (solid disc; the red part in Figure 9) is inserted into the orbital motion mechanism, which will be installed into the FRIEX large scale test set up available at DENYS.

The solid disc is held in position inside the solid disk holder (part in light grey colour in Figure 9) by an internal flange on one side and by a set of internal clamps on the other side, constraining the solid disk axially. There is no significant torque transferred onto the solid disk.

The rotor (green part in Figure 9), driven by the gears (in dark grey in Figure 9), imparts an orbital motion on the solid disk holder (in light grey in Figure 9) and thus on the solid disk (in red in Figure 9) by means of an eccentricity ring (light green, Figure 9).

The workpieces are clamped in sleeves (not shown for clarity) that fit accurately within the bores (in blue in Figure 9) located at either side of the solid disk, in such a way to allow axial movement towards the solid disk, but not allow any radial movement. An orbital motion is thus achieved between the cross section faces of the workpieces and the surfaces of the solid disk. This enables a friction welding process to be achieved uniformly across an irregular cross section. The full assembly with the FRIEX gearbox is illustrated in Figure 10.
Figure 9: Orbital motion mechanism
3.6 Design of the clamping mechanism for the rails

In order to weld rails end to end, each component must be clamped into a sleeve which will align the rails for joining, restrain the rails from any radial displacement during the welding process and enable the rails to be fed axially onto the face of the sold disk by means of the main hydraulic jacks, both during the friction and forging stages (Figure 11).

*Figure 10: Gear transmission with the inserted orbital motion mechanisms*
Industrial grade rails have a rolling tolerance which must be allowed for in the design of the rail clamp, and thus a small clearance of 1 mm nominal is provided around the rail profiles within the rail clamp sleeves.

Externally the rail clamp sleeves are machined to achieve a matching precision fit within the orbital mechanism bores, for reasons described above.

The rails are aligned within the sleeves making use of the taper profile which exists on the rolled profile of the rails between the underside of the rail head and the shoulder of the bottom flange. A taper profile is directly machined into one of the internal side faces of the rail clamp sleeve, which mates into the rail profile tapers (Figure 11). On the opposite internal side face of the rail sleeve, a similar wedge is provided, which again mates into the rail profile on the opposite side in a similar way. However, in this case, the wedge is actuated by hydraulic sliding wedges behind it, forcing the rail onto the fixed wedges and thus locating and fixing the rail against the reaction forces of the friction welding process (Figure 12). The rail is thus globally constrained.

In order to provide local lateral restraint to the rail head and the bottom flanges, clamping studs are provided, restraining them from local displacement during the friction welding process. The full assembly is illustrated in Figure 14. The existing clamp of the Friex machine is shown in Figure 15 and Figure 16.

![Figure 11: Cross section of the rail clamping system](image1)

![Figure 12: Rail clamping system](image2)
Figure 13: Rail clamping components

Figure 14: Rail Clamp mechanism assembly
3.7 Design of other auxiliary equipment for clamping of the parts

3.7.1 Sample holder

During the commissioning of the machine, and for subsequent testing of welded parts, small-scale welding trials will be performed using simplified samples like round or square bars. A sample holder has been designed for these initial tests (Figure 17 and Figure 18).

4 Conclusions

The required clamping tools for intermediate component and the rails to be welded have been designed and are currently being produced. It is foreseen that these components will be available around the same time the orbital motion device will be ready (end of Sept. 2016).
Figure 17: Design of the small scale sample holder
Figure 18: Sample holder mounted in the orbital motion mechanism (cross sectional view)