

# Refurbishing of girth gears with FCB Nova-Gear®

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## 1 Introduction

FCB Nova-Gear® is an on-site machining solution to refurbish the girth gears of rotary equipment such as rotary kilns and mills, without disassembling. FCB Nova-Gear® (► Fig. 1) recovers the involute form of teeth active flanks within the same dimensional tolerances as a new girth gear. It is a quicker and less-expensive alternative to a girth gear reversal usually performed after 20 to 25 years of operation. It is also a safer alternative to manual grinding operations, which are time-consuming, exhausting work for operators, and produce unpredictable results as it depends on the operator's precision. This unique and patented solution has been developed by Fives, which has been an OEM of rotary kilns and mills for the cement and minerals industry for over 85 years. FCB Nova-Gear® is one example among other products and services proposed by Fives to improve the reliability and extend the lifespan of production equipment.

## 2 Teeth profile and contact surface recovery

The normal wear on teeth causes irregular movements and therefore vibrations which may generate damage to the power transmission system (reducer, couplings, bearings...). In addition, a bad contact surface between the pinion and the girth gear can induce deep defects in material and accidental wear. FCB Nova-Gear® recovers the original teeth active flank profiles of the girth gear within the tolerances defined in ► Table 1. The pinion must be reversed or replaced by a new one to also provide a new profile on the active flank. The recovery of the involute profile of teeth and their straightness will ensure a good distribution of the load on the active flank between the pinion and the girth gear and a constant angular velocity ratio. ► Fig. 2 shows the machining head in action.

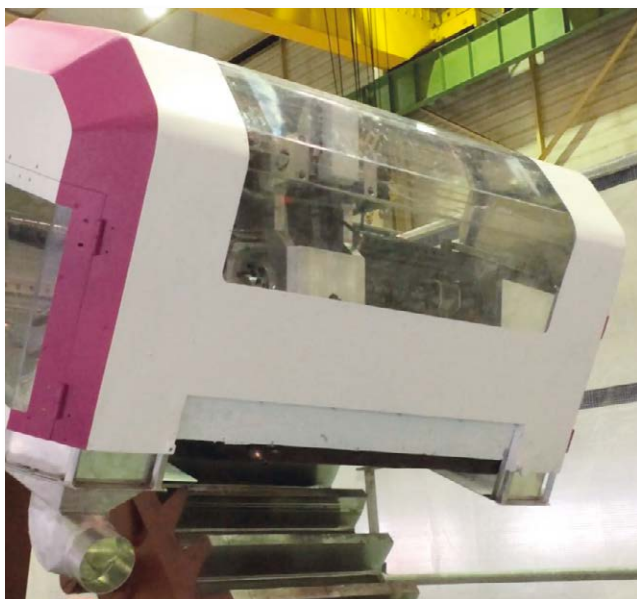


Figure 1: On-site automatic machining of a girth gear

Table 1: Dimensional and roughness tolerances

Dimensional and roughness tolerances	ISO 1328/ Class 9	FCB Nova-Gear®	Manual machining
Profile shape	< 0.1 mm	< 0.04 mm	< 0.15 mm
Straightness	< 0.1 mm	< 0.04 mm	< 0.15 mm
Roughness Ra	< 6	3.2 to 4	< 4
Single pitch	< 0.1 mm	< 0.1 mm	< 0.15 mm



Figure 2: Machining in progress on a rotary kiln girth gear (228 teeth, modulus 28, width 690 mm)

## 3 An automatic sequence of machining

The FCB Nova-Gear® machine is placed with a crane on the top of the girth gear. It takes position against the counter-flank on one tooth (► Fig. 3) and is secured by lateral thrusts and a fixed cable on the ground. Then the machine is shifted by an electrical winch without external handling system. It machines completely one tooth and goes automatically from tooth to tooth, starting at 45° angular position and moving to a maximum angular position of 75°. When this maximum inclination is reached, the girth gear must be rotated with the auxiliary drive to start a new sequence on the second sector of 30°.

During the machining of each tooth, FCB Nova-Gear® is strongly held to the girth-gear flanks with hydraulic jacks. The machining head works as a shaper. The same tool performs several roughing layer cuts and one last top-quality finishing cut. The final roughness Ra is between 3.2 and 4 and does not require the manual finishing process. The machine operates as a linear shaving tool and ensures perfect straightness as well as surface finishing unlike a milling tools reamer,

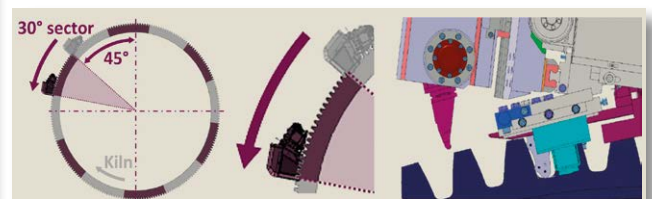


Figure 3: Automatic positioning and machining sequence

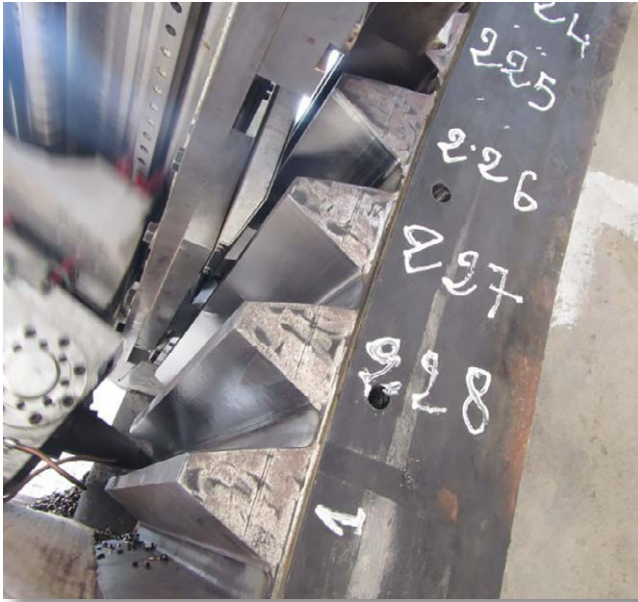


Figure 4: 5 mm thickness removed on 228 teeth in 57 hours

which generates defects in the surface. The appropriate rolling and sliding contact are recovered between the pinion and the girth gear, without stress concentration on the surface.

FCB Nova-Gear® has been developed thanks to the expertise of the Fives group in metal cutting equipment: the tools of Fives are operated worldwide in aerospace, automotive and energy.

#### 4 Striking speed and unmatched capabilities of thickness removal

Unlike manual machining, FCB Nova-Gear® is a maintenance solution without compromising quality and time. It can remove up to 8 mm thickness, when manual machining is limited most of the time to 2 mm due to tight stoppage schedules (▶ Fig. 4).

On an average, FCB Nova-Gear® can machine 1 mm on all the teeth of a girth gear in less than 48 h. Only 3 to 5 h are necessary for each additional millimetre, depending on the size of the girth gear. The machining time and the application range are indicated in ▶ Tables 2 and 3.

Table 2: Machining time in hours, given for a 550 mm width girth gear by 2 mm deep machining

Number of teeth	Module					
	20	26	30	32	36	40
160	25	33	36	36	40	44
200	33	36	40	44	47	51
240	36	44	51	51	58	62
280	40	51	58	58	65	73

Table 3: Application range

Girth gear width [mm]	450 to 850
Module	20 to 40
External Ø [mm]	3600 to 12000

#### 5 Case study n°1: FCB Nova-Gear® selected as an alternative to a girth gear reversal in Morocco

This operation has been performed in a cement plant in Morocco. The reversal of the kiln girth gear was initially planned but it has been cancelled because FCB Nova-Gear® was considered a cost-effective alternative.

- girth-gear machined: 228 teeth, modulus 28, width 690 mm
- thickness removed: 5 mm on all teeth
- 57 h of machining
- 250 kg of shavings collected

The remaining thickness was 90 % of the original dimensions (5 mm removed) and could have been reduced up to 70 % (15 mm) based on mechanical calculations. It means that the FCB Nova-Gear® can be repeated for future maintenance operations to extend the lifespan of the girth gear if material fatigue permits this.

The pinion has been replaced by a new one to compensate the backlash increase and prevent stoppage reverse rotation chocks, Fives can provide pinions specifically designed with thicker teeth).

As shown in ▶ Fig. 5, FCB Nova-Gear® is a clean machining solution, without cutting fluids. All the shavings have been collected.

#### 6 Case study n°2: FCB Nova-Gear® selected to remove surface damage in Saudi Arabia

This girth gear of 220 teeth, modulus 40, is installed on a recent rotary kiln in Saudi Arabia. The wear of the teeth profile is low (< 0.5 mm) but the misalignment between the pinion and the gear has generated spalling on the gear (▶ Fig. 6). Spalling is caused by high contact stresses. The risk of cracks propagation perpendicular to the surface is high. Those cracks can develop deeper in the teeth and increase the risk of breakage. The depth of the maximum shear stress is considered between 1 and 1.5 mm below the surface. Therefore 1.5 mm will be removed on all teeth.



Figure 5: Machining on a rotary kiln in a cement plant in Morocco



Figure 6: Low profile wear (0.4 mm), but important spalling

The position of the pinion will be adjusted to ensure a good contact-pattern. Fives will also perform a deep root-cause analysis to explain the accidental damages and provide recommendations regarding maintenance and lubrication (lubricant grade, system upgrade, tightness improvement etc.).

## 7 A full range of services

FCB Nova-Gear® is one example among the innovative solutions provided by Fives, which performs mechanical



Figure 7: Rotary kiln alignment control

inspections and maintenance operations all over the world for rotary kilns, dryers and tube mills, whatever the original manufacturer.

In this connection Fives has recently developed a new smart and comprehensive rotary kiln inspection method, including alignment control (accuracy  $\pm 0.5$  mm), with immediate delivery of results on site (Fig. 7). Detailed analysis, clear and visual reports are delivered to make the right maintenance decision. ◀