

CH03 - ExtruForm – a New Combined Rolling - Extrusion Process for Wire Rod and Sections

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Abstract

A fundamental analysis of existing processes used for the production of long extruded products, shows that no energy efficient method exist today. RUSAL in collaboration with the Siberian Federal University compared different processes: continuous casting and rolling, direct extrusion and the conform process, in terms of deformation schemes, metal flows and energy consumption. By introducing a combination of rolling and direct extrusion, the Combined Rolling – Extrusion (CRE) process was born. The characteristic deformation of the CRE process is a double-flow metal scheme with the use of active forces of friction. The process has many advantages: high single values of drawing, low energy consumption, good quality control, low CAPEX, small footprint (40 % reduction), fast tooling changes and low maintenance costs. The main disadvantage remains the relatively high extrusion tooling requirements.

All alloys 1xxx, 3xxx, 4xxx, 5xxx, 6xxx and 8xxx could be processed. The CRE process is predominantly used for wire rod production, however sectional shapes are possible, similar to conform process.

The first machine was co-engineered and built by the SMS-Group and is currently operating in one of the cast houses of the Irkutsk Smelter. The unit has a capacity up to 3 tonnes/hour.

Keywords: Continuous casting, Wire rod, Extrusion, Energy reduction, Innovation.

1. Introduction

The origin of the CRE or ExtruRoll process goes back to the collaboration between RUSAL and the Siberian Federal University. The Research at the Laboratories of Metal Forming pioneer new technologies and equipment to produce press-products from non-ferrous metals and alloys. One field of research is to find new ways to produce “long products” starting from liquid Aluminium.

Different processing routes have been established in industry over the years, starting from continuous casting and rolling (CCR); direct extrusion and Conform.

The deformation scheme of each process is different and every process has its pros and cons. Through fundamental analysis the concept of combined rolling and extrusion was developed. The ExtruRoll (CRE) process has a small industrial footprint, a very short lead-time from liquid metal to wire rod product, and a low specific energy consumption per metric ton.

1.1. Process Comparison

Continuous casting and rolling (CCR) is characterized by a single flow metal scheme. Cast bars are deformed into wire rod in several stages. The process is continuous but uses low single values of drawing.

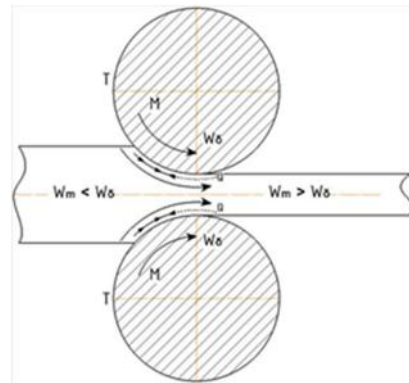


Figure 1. Continuous casting and rolling. Left: equipment and layout. Right: deformation scheme.

Direct extrusion has high single values of drawing but the process is discrete and requires pre-produced billets (casting, inspection, homogenization).

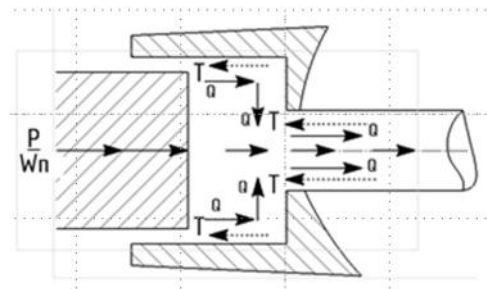


Figure 2. Direct extrusion. Left: equipment. Right: deformation scheme.

Conform uses pre-produced wire rod as input material to create smaller cross-sectional shapes.

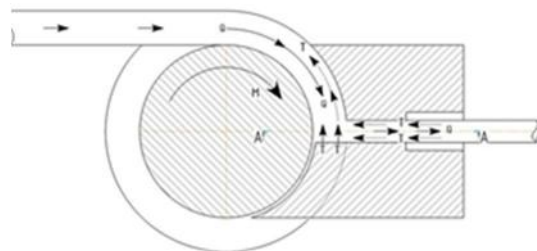


Figure 3. Conform. Left: equipment. Right: deformation scheme.

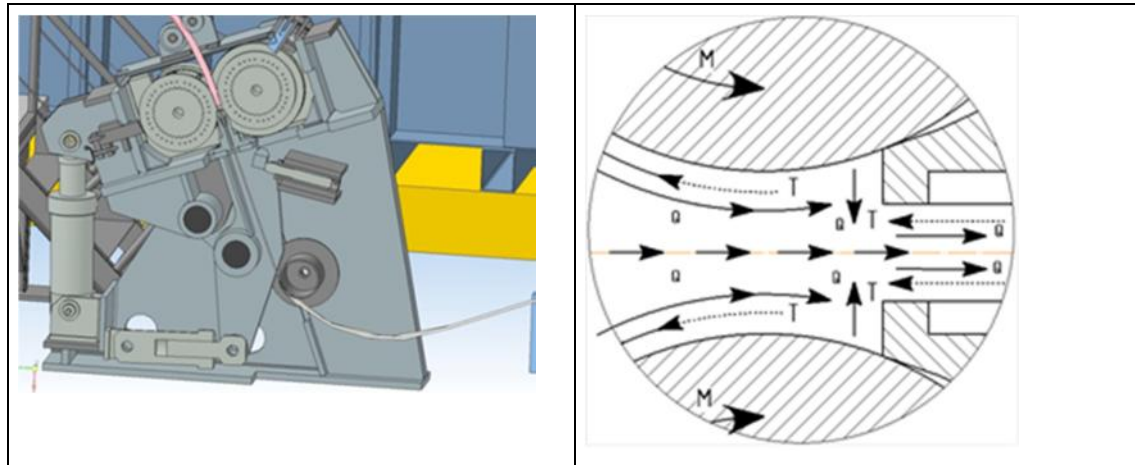


Figure 4. ExtruRoll process. Left: equipment. Right: deformation scheme.

The ExtruRoll (CRE) process uses the double flow metal scheme from the extrusion, in combination with the active forces of friction from the rolling process. The deformation rates are high and they range from 5 to 20.

Table 1 shows a comparison of the different processes.

Table 1. Process comparison for long aluminium products.

	CC & Rolling	Direct Extrusion	Conform	CRE
Deformation scheme	Single flow	Double flow	Double flow and use of active friction forces	Double flow and use of active friction forces
Advantages	High productivity	High single values of drawing	High single values of drawing	High single values of drawing, low energy consumption
Disadvantages	High energy consumption, low single values of drawing, risk of surface defects in rolling	Low productivity, high energy consumption, necessity to remove surface layer of billets (on hard alloys)	Low productivity, high energy consumption	High requirements on extrusion tooling

2. Development of the CRE Forming Process

After the initial design ideas, the process was modelled in DEFORMTM-3D, a simulation tool to analyze complex three-dimensional metal forming processes. In DEFORMTM-3D deformation and heat transfer are calculated in an integrated simulation environment. Material flow, forming load, energy, strain levels, temperature and tool stress are typical output parameters [1].

The CRE process sketch is shown in Figure 5.

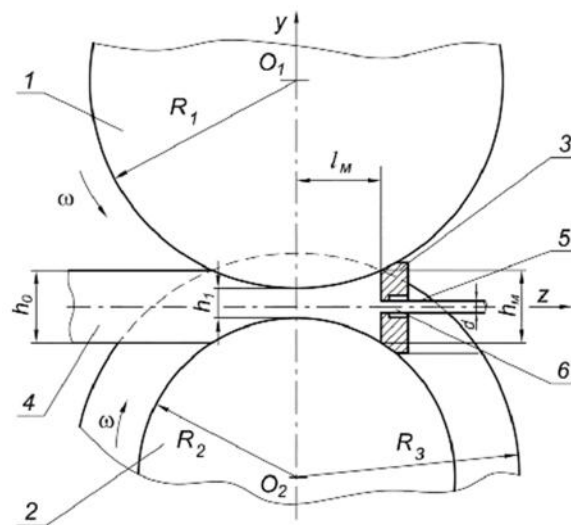


Figure 5. CRE process sketch.

The process modelling visualizes the metal flow in between the rolling wheels and the extrusion die. The flow pattern is shown in Figure 6.

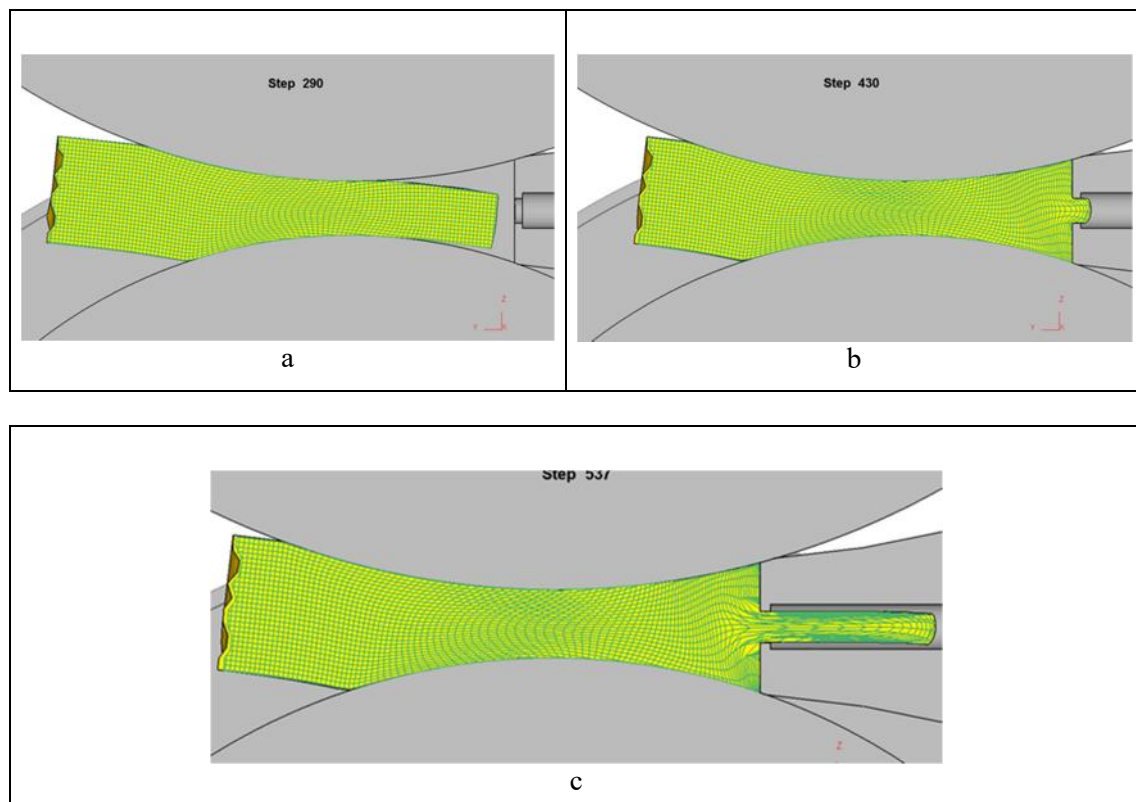


Figure 6. Coordinate grid of the metal flow pattern in the CRE process at the steps of rolling (a), pressing-out (b), and extrusion (c).

Three steps characterize the unsteady process stage. The first step involves gripping of the blank by the rolls with further rolling (Figure 6a). Then, metal is reduced in the gauge restricted by the plane passing through axes of the rolls and die face (pressing-out zone) until full filling (Figure 6b). When pressure developed by the active friction forces in the contact zone is sufficient for metal squeezing through the gauge die hole, the third step is started - extrusion (Figure 6c).

Metal temperatures are locally in the range between 450 – 500 °C and die pressures between 650 – 850 kN depending on the alloy and operating speeds.

SMS was selected as the preferred engineering partner and equipment supplier. The first pilot line was built and is operating in Casthouse #1 at RUSAL's Irkutsk Smelter.

3. Benchmarking the CRE Process to Conventional CC and Rolling

3.1. Throughput

The CRE process combines an extrusion process with the first rolling step of the cast bar. This limits the size of the cast bar cross sections. Conventional – CCR cast bars have cross sections of 3400 mm² versus CRE is limited to 1600 – 2400 mm². CCR lines can produce up to 6 ton per hour. For CRE the limit is currently at 3 ton per hour.

3.2. Alloys

CCR runs almost all alloys from 1xxx, 2xxx, 3xxx, 4xxx, 5xxx, 6xxx, 7xxx, 8xxx. The CRE pilot line was started with 1xxx. Process simulations of other alloy types have been conducted successfully, but the implementation and process development is still work in progress.

3.3. Mechanical Properties of Standard Conductor A5E Wire Rod

RUSAL operates several CCR lines to produce the standard 9.5mm diameter, A5E conductor rod. The CRE pilot line produces comparable quality and meets international standards. The wire rod is sold to customers around the world

4. Process Flow and Footprint Optimization

By comparing the three following Figures 7 to 9, it becomes clear which transformational changes wire rod production has seen over the years.

For some alloys, which cannot be CCR processed, it is necessary to first produce billets, scalp them and extrude them into wire rod, before subsequent drawing can be done to produce the required diameter.

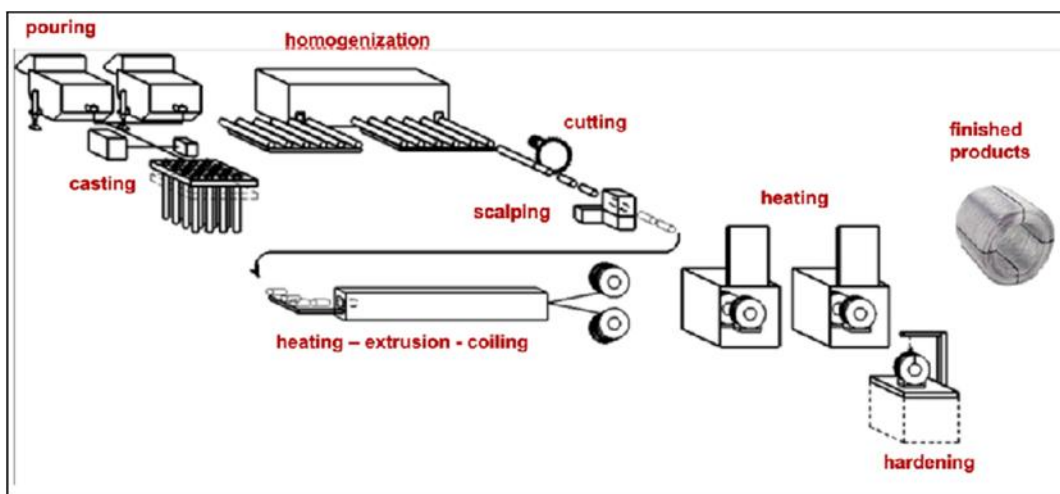


Figure 7. Billet production and wire rod extrusion.

Production footprint of ca. 11 200 m² and there is a time gap between processes.
 Continuous Casting and Rolling is the common method to produce most types of wire rod.

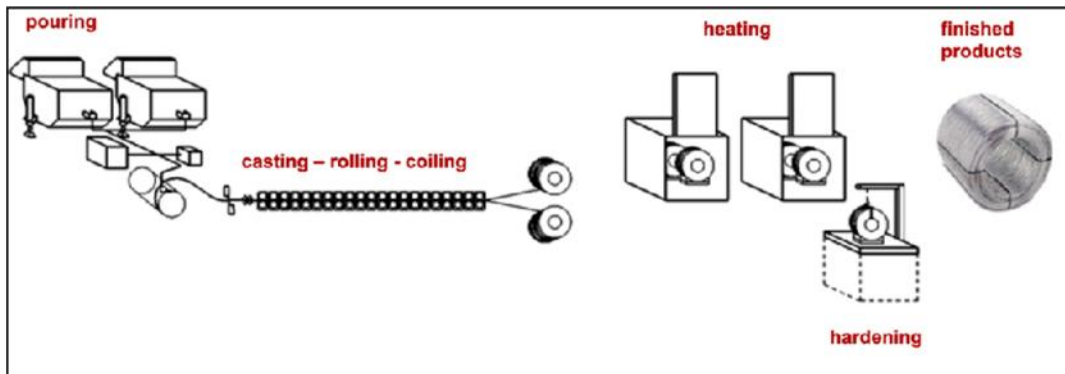


Figure 8. Continuous casting and rolling.

Production footprint of ca. 720 m² and there is a time gap between processes.
 The CRE is the most compact production flow of all, and eliminates the time gaps between the different process steps.

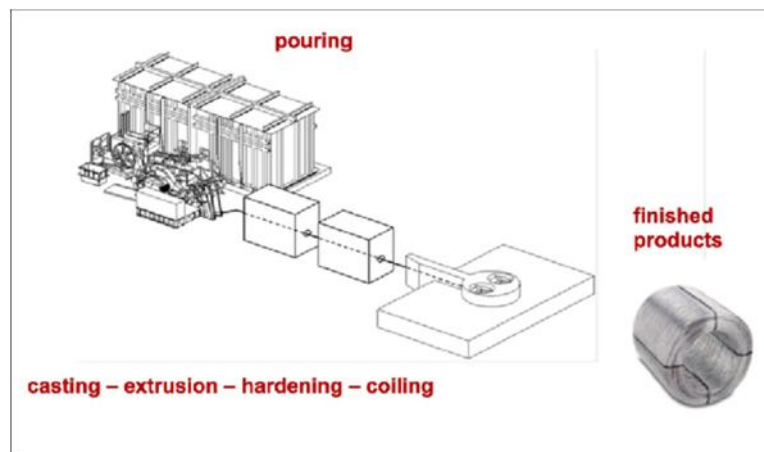


Figure 9. CRE process.

Production footprint is ca. 432 m².

Compared to conventional CCR technology for the production of wire rod, CRE offers advantages in:

- Low CAPEX
- Smaller footprint
- Fast change over times (SMED)
- Very short process lead time from liquid metal to finished product
- Low maintenance costs
- Low specific energy consumption

However more pioneering work is required to fully develop the potential of this novel process in the production of different alloys and shapes.

5. Product Portfolio of CRE

The process will be used to produce three types of products (see Figures 12 to13):

- wire rod for electrical power cables
- wire rod for welding wire
- grain refiner rod and sectional shapes



Figure 10. Electrical power cables.



Figure 11. Aluminium welding.



Figure 12. Grain refiner rod and sectional shapes.

6. Next Steps for CRE at RUSAL

The CRE pilot line in Irkutsk is both used for production, as well as process development. Focus is on:

1. Equipment improvements and process stability
2. Introduction of irregular shapes
3. Alloy range expansion

RUSAL aims to roll out the technology and build new lines for wire rod production in its smelters.



Figure 13. Casthouse #1 – RUSAL Irkutsk.

7. References

1. Denis S. Voroshilov, Sergey B. Sidelnikov et al., Simulation of combined rolling-extrusion process for round section billets in closed box caliber, *The International Journal of Advanced Manufacturing Technology*, (2023) 127, 2893–2910.