

# ECONOMIC WAY TO PRODUCE HIGH QUALITY COLD ROLLED STRIPS IN HIGH QUANTITIES<sup>1</sup>

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## Abstract

Against the background of a global market, rolling-mill owners are under constant pressure to cut their production cost and to open up new market segments with the help of innovative products. At the same time, requirements in terms of strip quality, such as thickness and flatness tolerances, surface structure and mechanical properties, are becoming stricter and stricter. SMS Demag as a provider of complete solutions for rolling mill equipment is faced with the task of taking appropriate actions in helping to achieve these targets. Therefore, conducting continuous and wide-ranging development activities is indispensable to SMS Demag. Long-standing solutions need to be questioned and new technologies examined for their usability and benefits in rolling installations. However, SMS Demag optimizes not only the equipment and develops new technical solutions, but also improves the mill concepts itself. Impressive examples of activities in this field are the introduction of the CSP concept and the compact cold mill concept. In this paper the PL/TCM will be discussed in more detail. The pros and cons of the concept in comparison with stand-alone solutions are given. Furthermore, the latest technology in pickling and cold rolling lines are presented, like the turbulence pickling technology, the new laser welder, the edge drop control, T-clean - a new lubrication and cleaning concept - and the on-line measurement systems provided by SMS Demag.

**Keywords:** Cold rolling; Pickling line; Tandem cold mill; Compact cold mill; Edge drop control; CVC plus<sup>®</sup>; Low quantity lubrication; T-clean.

## MODO ECONÔMICO PARA PRODUZIR TIRAS LAMINADAS A FRIO DE ALTA QUALIDADE EM GRANDES QUANTIDADES

### Resumo

Diante de um mercado global, os proprietários das usinas de laminação estão continuamente sob pressão para cortar seus custos de produção e conquistar novos segmentos de mercado, através de produtos inovadores. Ao mesmo tempo, as exigências em termos de qualidade da tira, como por exemplo, tolerâncias de espessura e planicidade, estrutura de superfície e propriedades mecânicas, tornam-se cada vez mais rigorosas. A SMS Demag, como fornecedora de soluções completas para equipamentos de laminação, assume a tarefa de desenvolver ações adequadas para ajudar a atingir estes objetivos. Por isso, para a SMS Demag é fundamental conduzir atividades de desenvolvimento contínuas e abrangentes. As soluções antigas têm de ser questionadas e novas tecnologias examinadas em relação à sua aplicabilidade e benefícios nas instalações de laminação. Entretanto, a SMS Demag não apenas otimiza o equipamento e desenvolve novas soluções técnicas, mas também aprimora a concepção da própria usina. Exemplos expressivos das atividades neste campo são a introdução do conceito de Produção Compacta de Tiras (CSP) e o conceito de Usina Compacta de Laminação a Frio. Neste artigo é discutida, detalhadamente, a linha de decapagem / laminação a frio em tandem (PI/TCM). É feita uma comparação entre os prós e os contras do conceito, em relação às soluções individuais. Além disso, são apresentadas as mais novas tecnologias para linhas de decapagem e laminação a frio, como a tecnologia de decapagem por turbulência, o novo soldador a laser, o controle "edge drop", um novo conceito de lubrificação e limpeza T-clean, bem como os sistemas de medição online fornecidos pela SMS Demag.

**Palavras-chave:** Laminação a frio; Linha de decapagem; Usina de laminação a frio em tandem; Usina compacta de laminação a frio; Controle "edge drop"; CVC plus<sup>®</sup>; Lubrificação mínima; T-clean.

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## 1 INTRODUCTION

The majority of investment decisions are based on the economical principles or facts. Today, the leading figure is the total cost of ownership, which includes not only the investment cost, but also the cost of installing, operating and maintaining a new facility. In the long term, the cost of maintenance, yield loss, staff and consumables separate standard mills and lines from economical and profitable ones.

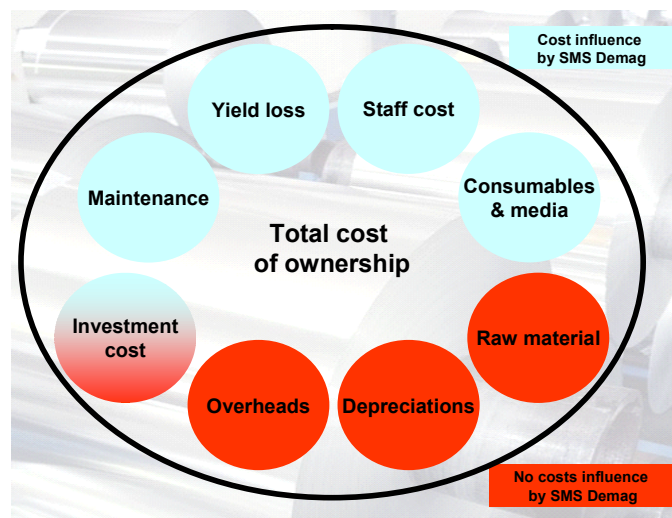


Figure 1: Investment evaluation via total cost of ownership

Looking at the cold rolling sector the cost of investment for mills are determined by the annual capacity required and in the long term cost-effective production of cold strip is only ensured if annual capacity and therefore the cost of investment, operation and maintenance of the facility match the actual annual production.

This paper presents and compares the available cold mill concepts and then discusses the tandem cold mill concepts coupled or not to the pickling line and the mill stand types in more detail and gives the pros and cons.

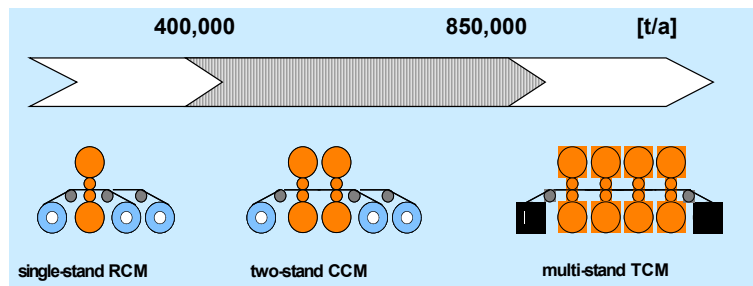
The latest technologies in pickling and cold rolling lines are also presented. These are

- Turbulence pickling technology
- Laser welder
- EDC<sup>®</sup> edge drop control
- T-clean, a new lubrication and cleaning concept
- Online measurement systems

## 2 COLD ROLLING MILL CONCEPTS

Today 3 different mill concepts are used in the cold rolling sector:

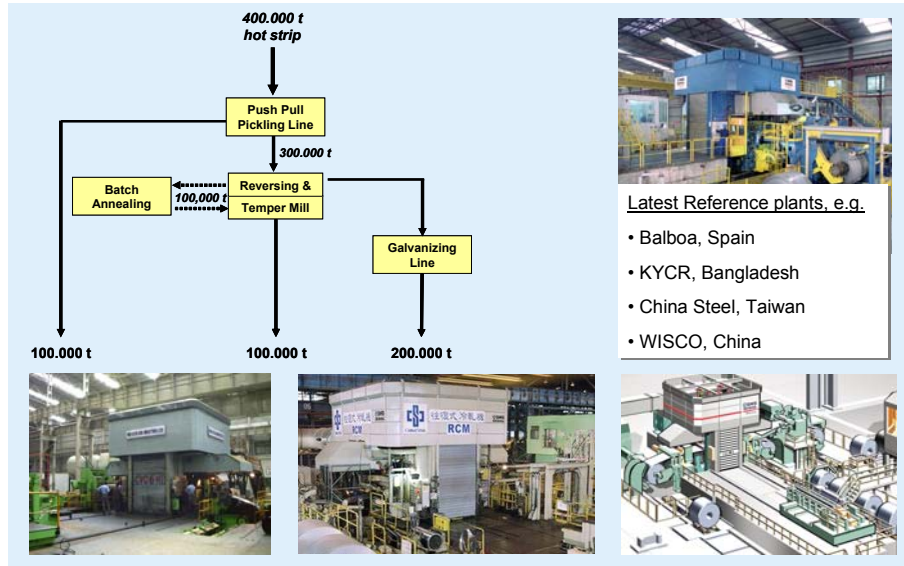
- The single stand reversing mill
- The two stand reversing compact cold mill and
- The tandem cold mill.



**Figure 2:** Cost optimized production through adequate cold rolling mill concepts

The single stand reversing mill offers a capacity of up to 450,000 t/a. These quantities of hot strip are typically pickled in low-cost push-pull pickling lines processing the coils one by one. After cold rolling, the hardened strip needs to be annealed above re-crystallization temperature before being tempered.

Up to a production of 300,000 t/a, individual rolling and temper mills are far below their production capabilities and thus would work uneconomically. A combination of both processes within one mill by processing coils lot-wise either in reduction mode or in temper mode reduces investment and operation costs. This combined reversing/temper mill is most cost effective for such quantities. Recent references of this type of mill are the single stand CVC plus<sup>®</sup> 6-HS reversing mill for KYCR in Bangladesh and a reversing/ temper mill with CVC plus<sup>®</sup> 4-high technology for Balboa, Spain. Both mills produce commercial steel quantities. References of mills for the production of special grades are the single stand CVC plus<sup>®</sup> 6-high reversing mills for China Steel, Taiwan, and for Wisco, China. Both mills are built to produce Si-Steel for the electrical industry.



**Figure 3:** Cold mill concept for low production

The medium range up to 800,000 – 900,000 t/year is covered by the Compact Cold Mill (CCM), a two stand reversing mill concept introduced by SMS Demag. The CCM concept closes the gap between the single stand mills and tandem mills with regard to the overall yearly production and the cost optimization of cold rolled products.

The CCM mill configuration with pay-off station and two finishing reversing reels offers high flexibility through multiple rolling strategies. Depending on the material grade and the required total reduction, single-pass, two-pass and three-pass

strategies are possible. The flexibility, however, is not limited to reduction modes, but also applies to 2-stand or single-stand temper or skin pass modes. In order to maintain flexibility for future increase in production, the two-stand mill can be extended with additional mill stands and linked to a pickling line thus creating a fully continuous PL/TCM, this means pickling lines coupled to a tandem cold mill.

**Latest orders awarded:**

**Jinan, China (startup: 2005)**

- Mechanics, hydraulics, electrics and automation supplied by SMS Demag

**Spaceframe, China (startup: 2006)**

- Mechanics, hydraulics, electrics and automation supplied by SMS Demag

**JSW, India (startup: 2007)**

- Mechanics and hydraulics, supplied by SMS Demag

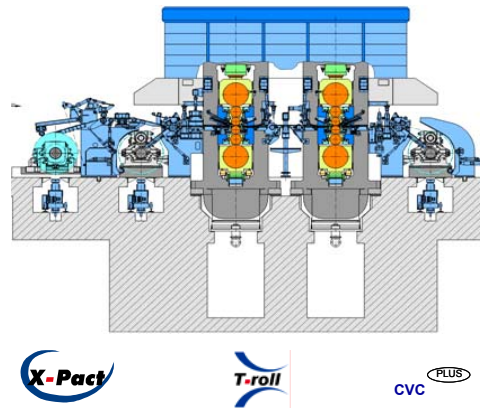


Fig. 4: CCM with a capacity of 800,000 t/year

With regard to the tandem mills, there are again 3 different concepts. These are the batch type tandem mill, the continuous tandem mill, and the tandem mill linked to a continuous pickling line.

The latter concept was offered worldwide for the first time by SMS Demag in 1979. Until today, 22 PL/TCMs have been built by SMS Demag and the concept has become a standard for the economical production of huge quantities of cold strip. The references of continuous pickling and tandem mills for the last 10 years are shown in Fig. 5.

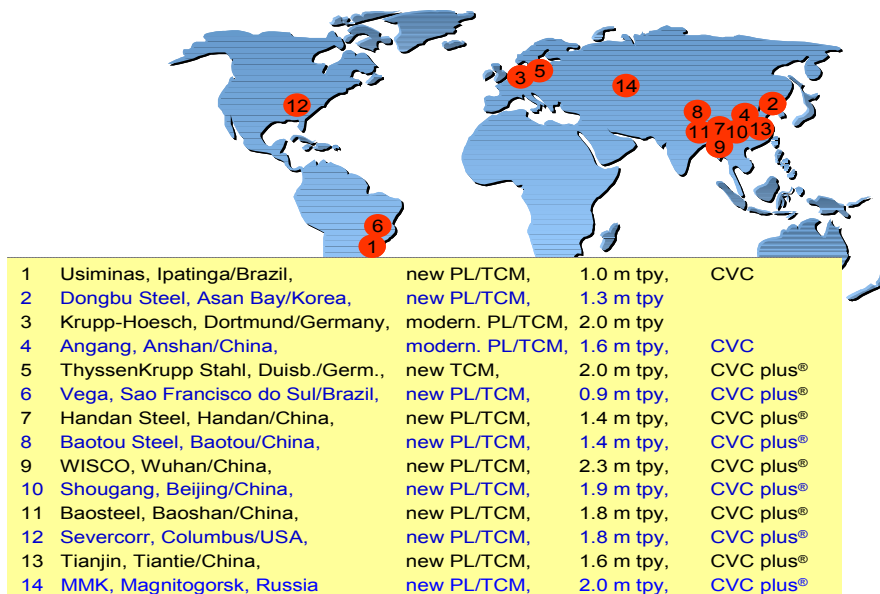


Fig. 5: References of continuous pickling and tandem mills (PL/TCM) of the last 10 years

### 3. COMPARISON OF TANDEM COLD MILL CONCEPTS

Tandem cold mills are used for the economic production of more than 900,000 t/a of cold strip, based on the assumption that mostly carbon steel is rolled. For the comparison of the different concepts, the following criteria are considered:

- Production capacity
- Conversion cost
- Investment cost

The three different concepts compared are shown in more detail in Fig. 6. To be able to compare all 3 concepts, a continuous pickling line CPL is considered in all cases. The main equipment items of the CPL are double pay-off reel group, welding machine, stretch bending leveling unit, the pickling and rinsing section, side trimmer and tension reel. The entry and exit loopers are also incorporated in the line in order to maintain continuous line operation.

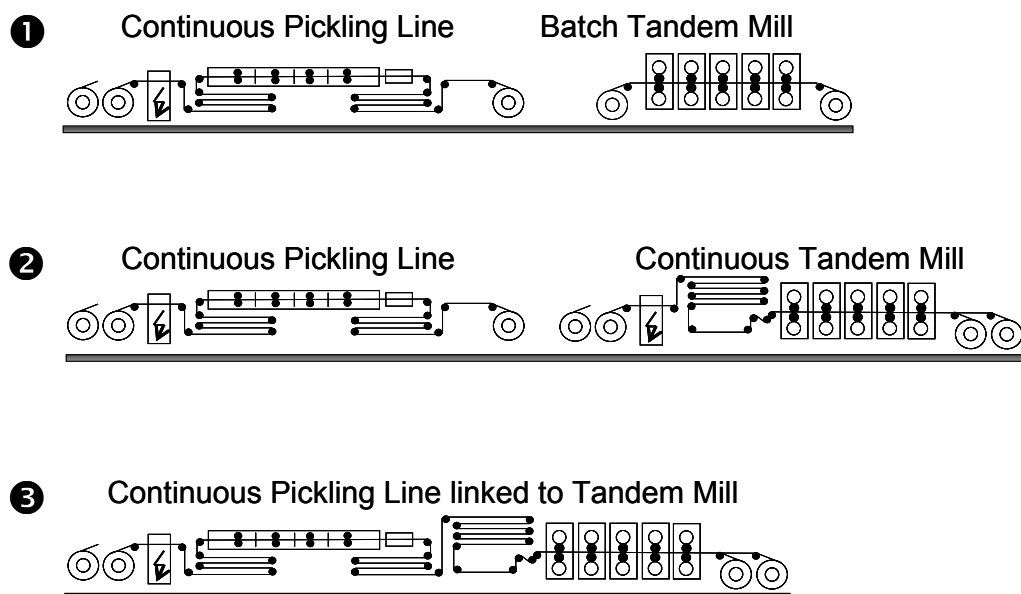


Fig. 6: Pickling line and tandem cold mill concepts

All tandem cold mills considered have 5 stands. In case of the batch line (TCM), the mill is equipped with a pay-off reel station and a tension reel. The continuous one (CTCM) is equipped with a double pay-off reel group, welding machine, entry loop accumulator and two tension reels. In case of the linked one (PL/TCM), the tension reel of the pickling line and the double pay-off reel group of the tandem mill as well as its welding machine are no longer necessary.

#### Production capacity

The production capacity of such concepts depends heavily on the product mix rolled and therefore on the material, the average width, thickness, and rolling speed. Keeping this in mind, stand-alone continuous pickling plants can be designed today with annual outputs of more than 2.5 m t/a. References to mention are the plant of

AK Steel, Rockport, USA, with 2.7 m t/a or the new one of Salzgitter Flachstahl GmbH, Germany, with 2.5 m t/a.

A batch tandem cold mill is able to produce up to 1.7 m t/a of commodity steels. A reference of such a tandem mill was the old ThyssenKrupp Steel tandem cold mill at Beeckerwerth, Germany. Up to 3.6 m t/a can be rolled with a continuous tandem cold mill. An impressive example for such a mill is the continuous tandem mill of AK Steel Rockford, started up in 1998 and able to roll carbon and stainless steel. Two pickling lines are needed to provide such a mill with pickled material.

The capacities of linked pickling lines and tandem mills supplied by SMS Demag range from 1.0 – 2.2 m t/a. From today's technical viewpoint, such a line can be designed with a capacity of up to 2.5 m t/a.

Considering all this together, the continuous tandem cold mill is the only concept available when a capacity between 2.5 and 4 m t/a desired. In the range below 2.5 m t/a, the continuous tandem mill is in direct competition with the PL/TCM, which covers the total range down to 900.000 t/a.

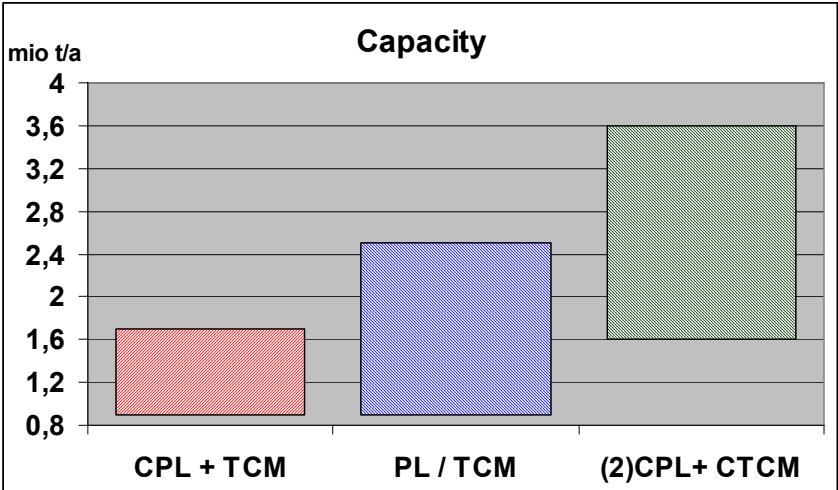


Fig. 7: Comparison of the production capacity

The batch tandem mill concept for the production of commodity steel grades is only of historical importance. Many mill owners keep them for rolling special steel grades. However, the quantities of steel grades produced which can definitely not be rolled on a PL/TCM are rather small. Therefore, such batch tandem mills are in direct competition with a single stand reversing mill or a compact cold mill. The competitive advantage of the batch tandem cold mill is that it is fully depreciated and investment for modernization is not as high as for a new CCM or, in some cases, even for a new reversing mill.

**Conversion cost**

The advantages regarding the conversion cost of the continuously operated tandem cold mills are related to energy, consumables and personnel.

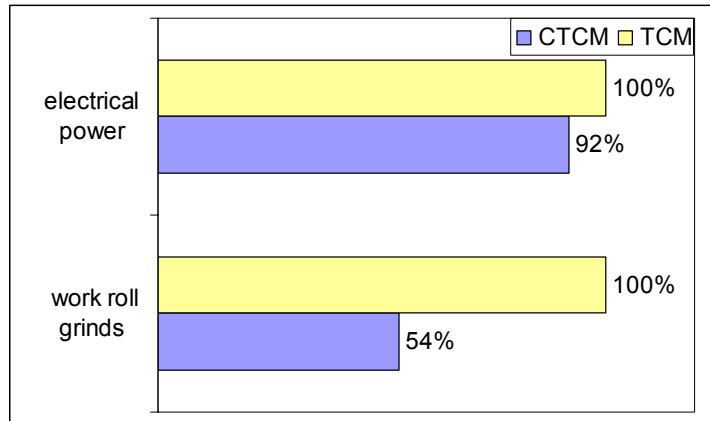


Fig. 8: Comparison of electric power consumption and work roll grinds for TCM and CTCM

The energy costs are reduced by the smoother operation. The savings connected to consumable costs are related to the work roll consumption. Due to the fact that threading in and out are no longer needed, marking of the rolls is avoided. This reduces the number of roll changes and increases the availability of the line. At the same time, continuous operation significantly reduces the number of coil breaks. All these facts plus the reduced roughness combine to nearly double the service life and life time of the work rolls.

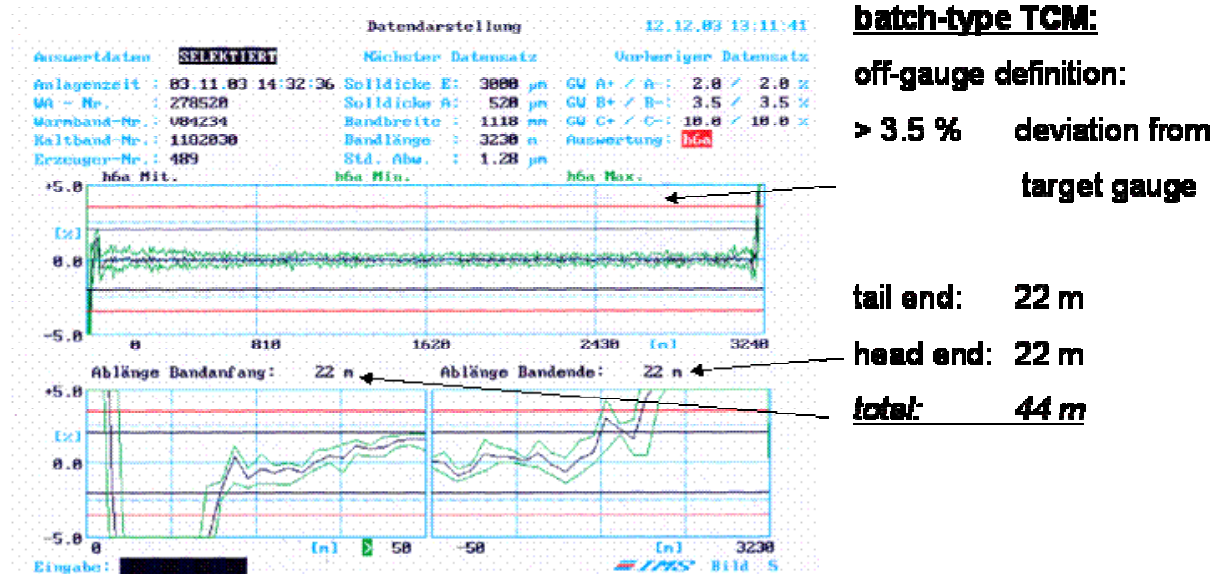


Fig. 9: Off-gauge length of a tandem mill

The off-gauge length is reduced to less than 15 meters. In a batch tandem cold mill, both at head and tail ends, more than 20 meters are out of tolerance. Moreover, the smooth operation improves the performance of the control systems and consequently the quality of the strip.

A further advantage of the PL/TCM is the avoidance of damage connected to coil conveyance and handling between the pickling line and the tandem mill, which is required in the other concepts.

A significant impact on the conversion cost is achieved by the reduction of the staff needed to operate the line. Some mill owners were able to reduce the staff by as much as 50%. Today, PL/TCM can be operated by a staff of 8 per shift. For operating a batch tandem cold mill with a continuous pickling line, 14 staff are needed, 13 staff must be available for the operation of a continuous tandem mill with continuous pickling line, and 16 staff for a high-capacity line with 2 CPLs.

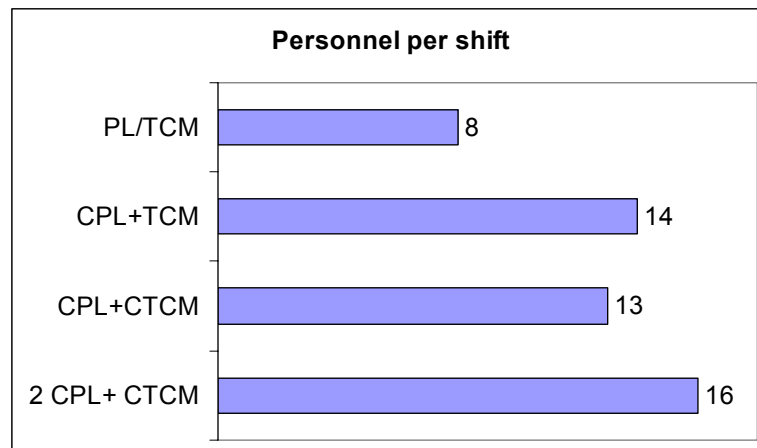


Fig. 10: Personnel per shift for different concepts

To summarize the discussion so far, the PL/TCM has the lowest conversion cost and the biggest number of advantages with regard to quality improvement. This is proven, also due to the fact that because of the coupling of the process steps of pickling and rolling, one step is waiting for the other from time to time. However, this statement is only correct for a capacity of up to 2.5 m t/a. Above this up to 4 m t/a, the CTCM with 2 CPL is at less equal compared to 2 PL/TCM.

### Investment cost

For comparison of the investment cost, the cost of the PL/TCM is set to 100%. Considering the main equipment items mentioned above, the difference in investment regarding the pickling line, when 1.2 or 2 m t/a are required, is less than 10%.

The following cost categories are distinguished:

- Mechanical equipment,
- Electrical and automation equipment,
- Land, foundation, buildings.

As expected, the batch tandem cold mill with continuous pickling line has slightly reduced investment cost compared with the PL/TCM. All other concepts exceed the cost of the PL/TCM in all categories. It is obvious that a continuous tandem mill requires more space, more mechanical and electrical equipment including automation systems. Again, the interesting point is how the situation presents itself if a capacity of more than 2.5 m t/a is required. As only the equipment, foundations and building directly related to the production facilities are considered in case of more



than 2.5 m t/a up to 4 m t/a, the investment cost for the PL/TCM solution is 200% in all categories. In this case, the solution with 2 CPLs and one continuous tandem cold mill is clearly the most economical one.

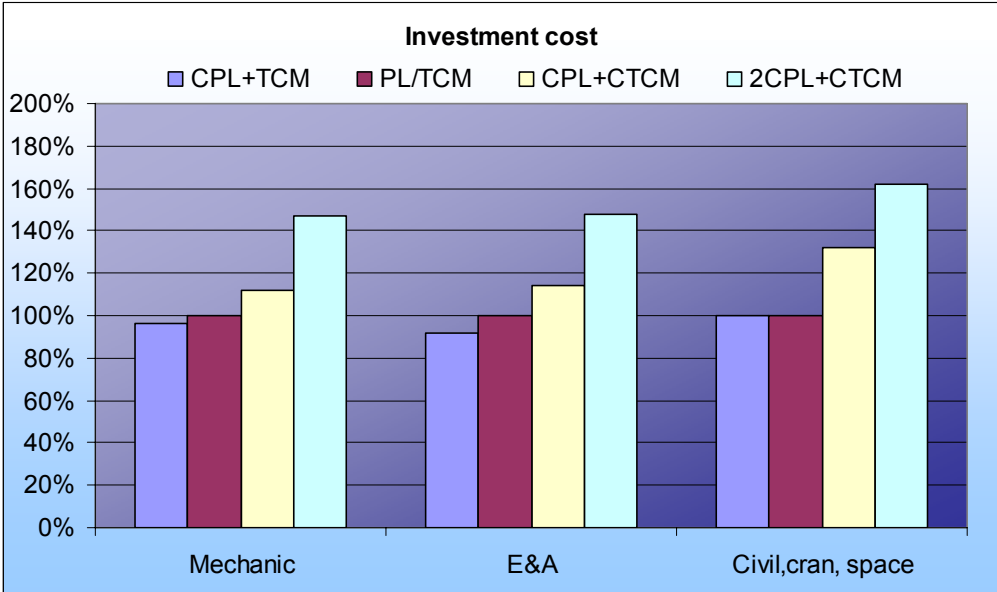


Fig. 11: Comparison of investment cost

**4. 4-HIGH OR 6-HIGH MILL STAND**

For the sake of completeness, a discussion of cold rolling mill concepts should also contain an argument about different types of mill stands.

In the past 10 years nearly all tandem mills built by SMS Demag have been equipped with CVC plus<sup>®</sup> 6-high technology in all stands. Exceptions are Vega do Sul, Brazil Severcorr, USA and the latest reference MMK, Russia. However, both mill stand types have their advantages and their disadvantages.

The 6-high concept offers the opportunity of using more actuators to influence the roll gap. Through CVC plus<sup>®</sup> contour on the intermediate roll (IMR), the intermediate roll bending and the work roll bending, the 6-high stand has a wider and more flexible setting range to adjust the roll gap to suit the incoming profile and flatness. Especially during flying product change, the required adjustment of the shifting position can be completely compensated by IMR bending, a feature which allows fast reaction during product changes. This is important especially in the last stand. Furthermore, the edge drop can be controlled by work roll shifting and with the help of a tapered work roll. Finally, it has to be mentioned that the work roll diameter can be smaller, which increases the reduction per pass; however, the slip limit and the contact loads needs to be considered.

All this requires more equipment to be installed and more rolls to be ground and replaced, so it requires higher investment and causes higher operation cost. The question is whether the benefits are worthwhile.

If edge drop control is not required, the product requirements also for high strength steel grades can be met by a 4-high mill stand. Maybe the adjustment of the no quadratic profile portion takes longer after product change. This, however, is without any impact on the process stability.

The stiffness of a 4-high stand is higher than that of a 6-high one, which is preferable with regard to thickness control. Nevertheless, close thickness tolerances are also met by 6-high stands.

Stand No.	Task	Features	4 high	6 high
1 - 4	Thickness Reduction	Flexible roll gap setup during flying production change and after roll change	++	++
		High cross stiffness of the mill stand for better thickness control	++	+
		Edge drop control for a constant thickness up to the edge	o	++
5	Flatness + Roughness	Adjustment range for flatness control	+	++
		Adjustment speed for flatness control during flying product change	+	++
	Economical aspects	Investment cost for equipment	+	-
		Investment cost for spare parts	++	+
		Production costs due to roll wear	++	+
	Conclusion	The 4-high with CVC plus® is the most economical solution when edge drop control is not relevant		

Tab 1: Comparison of 4-high and 6-high  
(++ strength, + acceptable, - drawback, o possible with effort)

Using a 4-high stand; also edge drop can be reduced down to 5–10 µm, but without CVC. In this case, the work rolls are provided with a crown according to the load expected and only the work roll bending is available for flatness control.

Bigger work roll diameters are preferable in the last stand; these ensure a longer service life of the work roll thus reducing the number of roll changes. To ensure an excellent flatness of the finished product, flexible actuators are desired. A 6-high provides this flexibility with CVC plus® and multi-zone cooling. Again, also a 4-high stand meets the requirements of the products using these actuators.

To conclude, 6-high stands offer higher flexibility in adapting to different process situations and allow the use of CVC plus® and edge drop control at the same time. However, this mill stand causes higher investment and operation cost and edge drop control makes sense only for few products. Therefore, from case to case, it is to be discussed whether the higher investment and operation cost can be compensated by improved product quality. If this is not the case, a 4-high stand is the most economical solution.

## 5. LATEST TECHNOLOGY IN PICKLING LINES AND TANDEM COLD MILLS

### Pickling line technology

The pickling line is designed as turbulent type, a technology developed by SMS Demag. It is characterized by

- Operation at high strip tension for improved strip guiding;
- Small height of the channels ensures high acid flow velocity, heavy turbulences and a much faster adjustment of the acid temperature; this improves process flexibility;
- Significantly lower steam and power consumption as well as acid losses due to the patented immersion covers;
- No pickling and rinsing inhibitors are needed due to the good controllability of the process.

For a pickling line producing about 1.8 m t/a, annual savings may total € 600,000 just because of the above-mentioned features. Due to the optimisation by SMS Demag, this technology is not only the most effective, but also the most economical one in terms of operating cost.

The latest development of SMS Demag in pickling line technology is the new laser welding machine LASERTEC developed together with Oxytechnik, a German welder manufacturer.

The laser welding technology is the first choice for continuous pickling lines. It allows the welding of thinner strips and strips having higher amounts of alloying elements with higher accuracy. In addition, this technology is cheaper than flash butt welders. The laser machine is equipped with a robust, mill-type design dividing shear with automatically adjustable knife gaps and fast knife-change device. The strip is aligned to the centreline of the leaving strip. This is achieved without pushers and hence damage to the strip is avoided.



Fig. 12: Welding cycle of the new welding machine

The first installation will be in the new 2.5 million t/a continuous pickling line of Salzgitter Flachstahl GmbH.

## Tandem cold mill technology

In order to meet highest quality requirements and to curb production cost, SMS Demag developed a large number of suitable solutions for tandem cold mills to support mill owners in their effort. Three examples are explained in more detail:

### System for edge drop control, EDC®

This system is based on separate control strategies for reversing cold mills and tandem cold mills. Operational results of CSC reversing mills in Taiwan and the tandem cold mill of ThyssenKrupp Steel Beeckerwerth, Germany, underline the suitability of the approaches chosen.

### T-Clean, a new lubrication and cleaning concept

This new lubrication and cleaning concept was developed by SMS Demag together with its partners of Air Products and CD Wälzholz, as a combination of low quantity lubrication and the utilization of liquid nitrogen.

The operating experience showed that the use of nitrogen more than doubled the work roll service lives. This advantage and the lower refinishing effort on the strips led to a cut of the process costs of skin-passing by approx. 20 % at our cooperation partner CD Wälzholz.

The most recent reference of this concept is the new inline skin-pass mill stand for the continuous annealing line of ThyssenKrupp Steel in Dortmund, Germany.

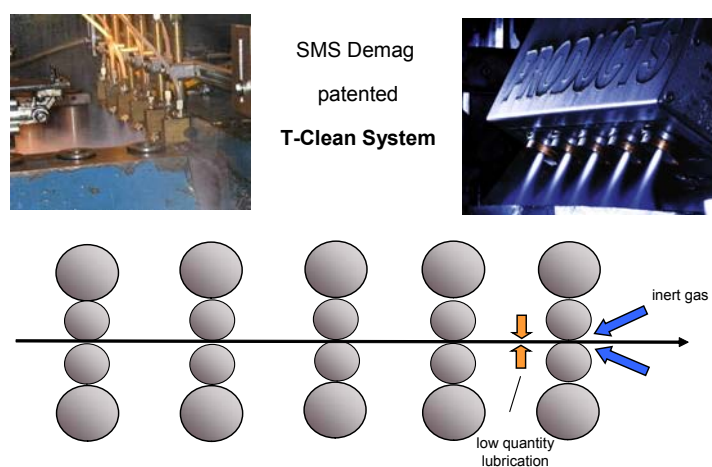


Fig. 13: Application of T-Clean system on a tandem cold mil

First results of the application of T-Clean on the last stand of a tandem mill show similar improvements.

### Online measuring systems

Efficient production on a high quality level today requires complete documentation of the main quality parameters.

Our new inline inspection line “Rotary Inspect” sets the record here for safety and ergonomics in the manual assessment of strip top and bottom sides.

Our patented roughness control system makes it possible to control strip roughness over the entire length to a constant value and to perform the roll change only when it is really necessary. For roughness measurement, the SORM 3 Plus measuring system of our cooperation partner EMG is used.

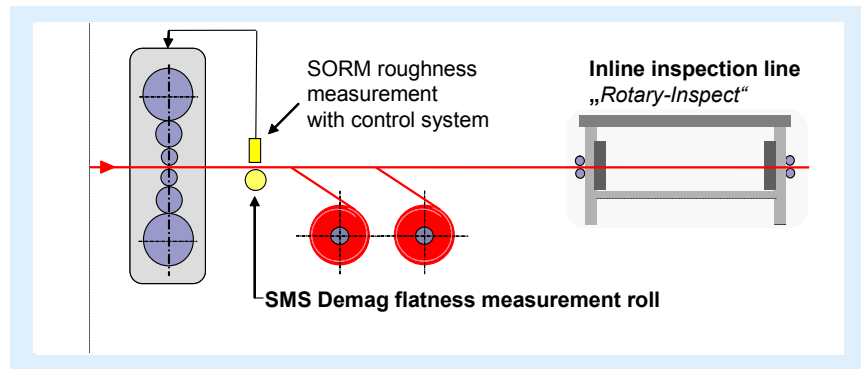


Fig. 14: Online measurement systems and inline inspection line

The SMS Demag flatness measuring roll is the ideal solution for precise and reliable measurement of strip flatness. The closed surface of the roll avoids marks on the strip and can be specifically coated for every application. The roll allows simple installation of the sensors, which can even be performed on site. The sensors can be flexibly arranged with regard to their distances in accordance with the current and future requirements of the profile and flatness control system.

Ten references within a short time demonstrate the high degree of acceptance of this online measuring system by our customers.

## 6. CONCLUSION

Nowadays, the business environment in the steel industry is changing dramatically. All over the world, companies merge into global giants having production facilities all over the world. In China, but not only in China, new production facilities using the latest technologies are built with enormous capacities

Under this circumstance, well established concepts must be questioned as it has been done in this paper for the PL/TCM. As a result, it can be pointed out that the old concept of decoupled continuous pickling line and continuous tandem mill is the most economical solution for an annual capacity in the range of 2.5- 4 m t/a. The answer to the question whether such a mill should be equipped with 6-high stands or with stands depends on whether EDC<sup>®</sup> edge drop control is needed or not. If EDC<sup>®</sup> is not needed, the 4-high stand with CVC plus<sup>®</sup> is the most economical solution. However, the final decision as to which concept is the economical one can only be taken under consideration of the specific situation prevailing at the respective company.

Furthermore, the latest technologies in pickling and cold rolling lines are presented, which support mill owners in their efforts to achieve a more economical production.