Machinery and plant for the production of oilfield tubulars

The rising worldwide demand for oil and gas is leading to ever deeper wells with ever higher temperatures and pressures, often associated with sour conditions such that the use of low-alloy steel, high-alloy stainless steel, nickel-based alloys or titanium alloys for tubulars is usually necessary. The SMS group aims to meet these demands through supply of complete plants for the production of tubulars up to 406mm in diameter, plus modernisations and upgrades, modern information technologies and the right maintenance strategy.

Authors: Dr.-Ing. Hansjörg Hoppe and Dr.-Ing. Hans Pelster
SMS group

The rising worldwide demand for oil and gas is leading to ever deeper wells such that depths of 7,620m (25,000ft) and more, are no longer unusual. Generally speaking, increasing depths mean increasing temperatures and pressures, and many high-pressure and high-temperature (HPHT) wells with temperatures up to 204°C (400°F) and pressures up to 138MPa (20,000psi) have already been drilled.

The real challenges for the materials from which the oil country tubular goods (OCTG) are produced arise during oil and gas extraction and, depending on the temperature, pressure, flow velocity and corrosive constituents in the gas stream, such as H_2S and CO_2, the use of low-alloy steel, high-alloy stainless steel, nickel-based alloys or titanium alloys is necessary.

The use of oilfield tubulars made from high-alloy materials is always necessary when one of the following concentrations in exceeded in the oil or gas stream:

- pCO_2 >1,500psi
- Cl-concentration >250mg/l
- pH_2S >10psi
- Temperature >200°C (390°F)

Commonly used high-alloy and corrosion-resistant materials are duplex steels (22Cr-5Ni), super-duplex steels (25Cr-7Ni-N), super-austenitic steels such as alloy 28 (28Cr-32Ni), nickel-based alloys such as alloy 825 (42Cr-21Cr-3Mo) or titanium alloys such as Ti Grade 5 (Ti-6Al-4V). The material chosen for a particular application depends on the corrosion conditions.

Currently most manufacturers are limited in the production of large-diameter, high-alloy oilfield tubulars that have to be cold worked in order to achieve the strengths necessary for such deep wells. There is a growing demand for tubes and casings up to outside diameters of 273mm (10.8in) and appropriate lengths from 9 to 12m (30 to 40ft).

SMS GROUP

The SMS group as a system supplier offers its customers tailor-made solutions for the production of OCTG. This includes primary steelmaking, secondary steelmaking and casting plants for the melting of high-purity stainless steels and nickel-based alloys, hot-finished, high-alloy oilfield tubulars or mother tubes that still have to be cold-formed can be produced in the diameter range 33.4 to 324mm (1.3 to 12in) on extrusion press lines. Cold-rolled tubes in the diameter range 5 to 280mm can also be produced.

SMS also offers complete hot and cold processing lines as a package solution. These include, in addition to the core machine, such as extrusion press lines or cold pilger mills, machines for billet preparation, pickling and degreasing facilities, finishing and testing equipment – in some cases from subcontractors.

PRODUCTION OF HIGH-ALLOY OCTG

Billet production Stainless steels or nickel-based alloys are melted in an electric arc or induction furnace under the exclusion of air and further processed via argon-oxygen decarburisation (AOD) or vacuum-oxygen decarburisation (VOD). If the batch size allows, continuous casting of round blooms is used, otherwise ingots are produced. Simple austenitic steels can be extruded directly without prior hot forming, but higher alloy materials must first be forged or hot-rolled in order to break down the as-cast structure and achieve a more homogeneous microstructure. After casting, the blooms or ingots are rolled to the required billet size or forged on radial forging machines then, in the final work step, the rolled or forged billets are peeled in order to create the surface quality necessary for the extrusion process. In the subsequent preparation section, the peeled billets or bars are sawn to length, a pilot bore is drilled in the end and the face of the billet is machined to produce an outer radius and inner cone at the bore. After ▷

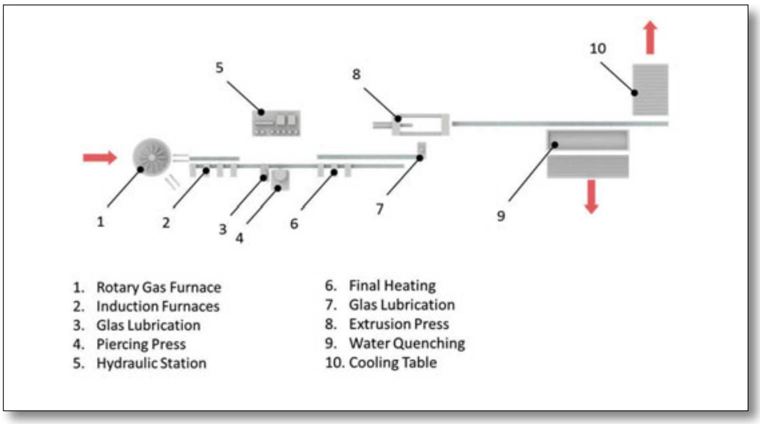

Fig 1 **Layout of extrusion press line**

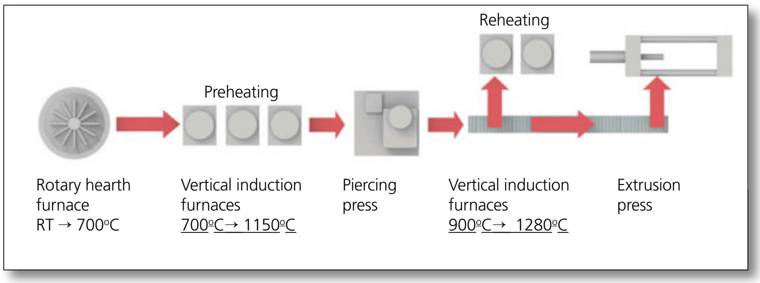

Fig 2 **Heating concept**

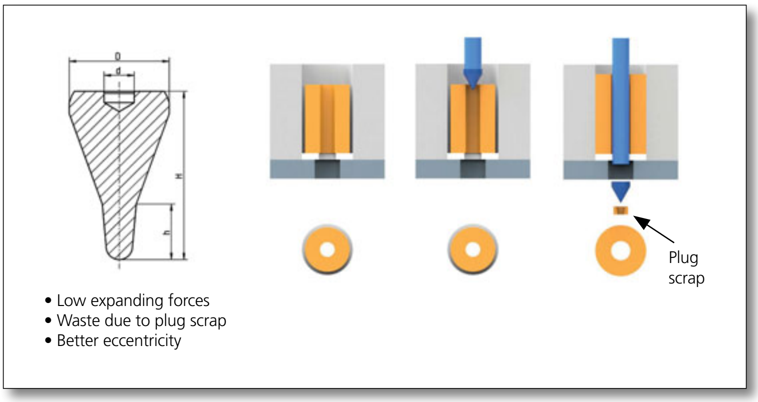

Fig 3 **Expanding process**

billet preparation, the machined billets are degreased on the inside (bore) and outside before they are transported to the extrusion press line on pallets.

Extrusion process The extrusion press line consists of a preheating station, billet lubrication unit, vertical piercing or expanding press, reheating station, billet lubrication unit, horizontal extrusion press and the run-out section with downstream water or air cooling of the extruded tubes (see *Figure 1*).

Temperature control Billet heating to the required temperature of 1,100-1,150°C is performed either in rotary-hearth furnaces with a reducing atmosphere, in induction furnaces, or in a combination of the two with a gas-fired furnace used as a pre-heater up to around 700°C and final induction heating in vertical coils (see *Figure 2*).

The SMS design of rotary-hearth furnaces produces a slow heating rate resulting in more uniform heating and a homogenising effect on the microstructure. The cost benefit of gas heating is particularly good if there are infrequent alloy changes and three-shift operation. Where there is the possibility of a rapid temperature change for small batch sizes or where the line is not operated in three shifts then induction heating may be preferred. Induction furnaces can be expensive to operate, but they heat up quickly and can control the temperature very precisely, an aspect of great importance with the narrow temperature ranges within which stainless steels are extruded. A combination of rotary-hearth furnace and vertical induction heating is therefore a very flexible solution, particularly suitable for high-alloy materials.

After heating to approximately 1,150°C, the billets are transferred to the vertical expanding and piercing press where they are expanded to a defined inside diameter or pierced directly. Before piercing, the billets are lubricated on the inside and outside with SiO_2-based glass powder which melts on the hot billet surface and forms a thin, low friction lubricating film. This film also has a heat insulating effect and protects the billet from secondary scaling.

The expanding and piercing press is of vertical design with a shifting container. It has an innovative cylinder construction that permits upsetting and piercing with the same cylinder pair. Furthermore, the press has extensive ancillary facilities for billet and expander manipulation.

The billets are mechanically pre-drilled as standard which gives better eccentricity, however there is some waste due to plug scrap (see *Figure 3*). For pipes with a large inside diameter, piercing without a pilot bore is performed after brief upsetting with the upsetting ram (see *Figure 4*). Displacement piercing then transitions into rise piercing. Higher piercing forces are necessary and this method is less accurate. In order to avoid excessively large discards, the underside of the billet is closed off by a closing cylinder until shortly before the mandrel pierces the base, ▷

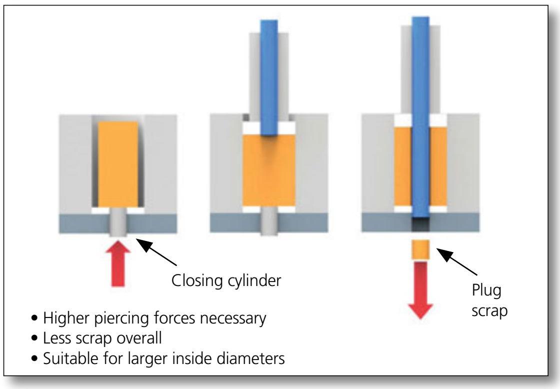

Fig 4 **Piercing with prior upsetting**

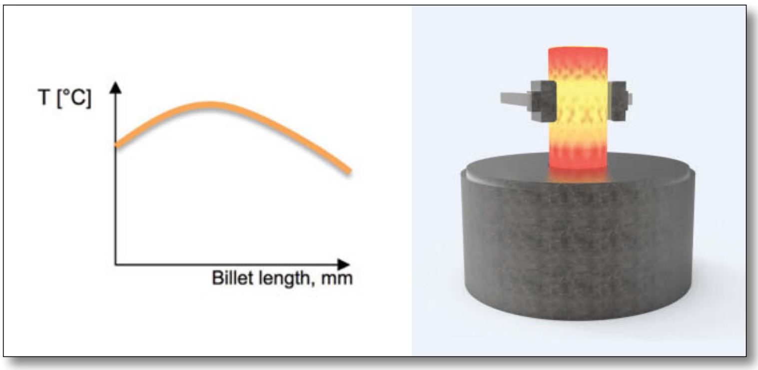

Fig 5 **Temperature distribution in the billet after expanding/piercing**


Fig 6 **Example of multi-zone heating**

but due to the lack of the pilot bore, the material losses are generally lower.

After expanding and/or piercing, the billet cools at different rates and has an uneven temperature profile before entering the reheating station (see *Figure 5*). The temperature profile of the billet is marked by a significant temperature drop between the billet ends and the centre and between the billet surface and the core, which can be more than 200°C.

Induction heating In order to compensate for this uneven temperature distribution and to raise the process temperature to 1,180-1,250°C, induction reheating plays a crucial role in the whole heating process. One of the most important developments in induction reheating is multi-zone heating (see *Figure 6*). The vertical induction heaters with multi-zone heating have been supplied by IAS GmbH, a member of the SMS group since 2002. *Figure 6* shows two multi-zone heaters in the background.

The coils are divided into several vertical sections that are controlled separately with variable frequencies. The billets can thus be heated individually in each zone according to their temperature profile without overheating the material.

Each reheating coil is connected to an inverter with multiple converter technology, allowing the temperature profile even of billets of different lengths to be optimally equalised. The inverter is able to supply electrical energy up to four zones in each coil fully independently. Variation of the current frequency influences the penetration depth of the electromagnetic field, and hence the radial temperature distribution in the billet (lower frequency means deeper billet heating).

On reaching the specified extrusion temperature, the billets are again lubricated on the inside and outside and loaded into the extrusion press. A glass disc is located in front of the die which melts during the extrusion process, surrounding the leading end of the tube. The thickness of the glass layer on the tube surface is about 10µm. Careful matching of the glass type, extrusion temperature and extrusion speed as well as the glass volume is important in order to obtain a uniform glass coating on the strand. If too little glass flows through the die, scores are produced on the surface; if the glass volume is too high, an orange peel skin is formed with some large individual microstructure grains.

The high billet temperature of high-alloy materials demands rapid transport from the furnace to the press, particularly so with small billet diameters with their large surface area to volume ratio, otherwise the material would cool too quickly. After upsetting of the billet in the container of the extrusion press, the tube is extruded within a few seconds. A short extrusion time is necessary in

Year	Customer	Country	Extrusion press tonnes	Piercing press tonnes	Material
1988	Volski Tube, Volgograd	Russia	5,000	2,500	Stainless steel, C steel
1990	Special Metals Wiggin*	UK	5,800	-	Nickel alloys
1992	Sandvik Choksi	India	1,250	-	Stainless steel, C steel
1996	Cezus	France	3,300	-	Stainless steel, zirconium
1998	Salzgitter Mannesmann Stainless Tubes*	Germany	3,000	1,500	Stainless steel
2000	Hoesch Hohenlimburg* predominantly profiles	Germany	1,600	-	Stainless steel, C steel
2002	RTI Fabrication, Houston	USA	4,500	-	Titanium
2008	Centravis Nikopol	Ukraine	4,400	1,250	Stainless steel
2010	Baosteel Group	China	6,000	2,500	Stainless steel
2010	Tisco	China	6,000	2,500	Stainless steel
2011	Chepetsky Metallurgical Plant	Russia	3,500		Stainless steel, titanium zirconium
2013	Western Energy Material	China	4,500		Stainless steel, titanium zirconium
2013	Salzgitter Mannesmann Stainless Tubes*	France	4,000	1,250	Stainless steel
2015	SeAH Changwon Speciality Steel	Korea	5,000	2,000	Stainless steel

*Modernisation / press force increase

Table 1 **Reference list – steel and special metal presses**

order to minimise the contact time with the die, since the dies should preferably not exceed 500°C. The necessary ram speeds therefore lie between 150 and 300mm/s, depending on the extrusion ratio. High extrusion speeds are only possible with an hydraulic accumulator drive and today, oil hydraulics is standard even on extrusion presses for steel tubes.

Figure 7 shows an example of a steel tube extrusion press (centre), with the furnace for tools on the left and control cabinet on the right. Numerous examples of tube extrusion presses for high-alloy steels, titanium, nickel or zirconium alloys are summarised in *Table 1*.

Post extrusion processes Downstream of the extrusion press, the tubes have to be quenched in a water tank in order to achieve their quality characteristics and prevent carbide precipitation and intermetallic phases. In order to avoid distortion and deformed tubes due to the quenching process, water is sprayed selectively and under high pressure on to the tube surface by a water spray system. Particularly with smaller tube dimensions, this ensures a straightness that is crucial for further tube handling.

The press has ancillary facilities that permit highly automated operation of the plant, for example, discards can be separated from the dummy block in semi-automatic mode by the discard separator. Fully automated die changing is also possible. As with the piercing press it is also possible on the extrusion press to clean the container on the inside and to cool the mandrel from the outside, and optionally, also from the inside.

Downstream of the extrusion press, the extruded shells are finished using equipment such as a 10-roller straightener, cut-off facilities and pickling baths. Straighteners above approximately 100mm tube diameter are core components of the plant. After non-destructive testing, visual inspection, marking and packing, the hot-finished tubes can be delivered directly to the customers for further processing, depending on the application.

Pilger operation Hot-finished mother tubes are delivered to the pilger shop and further processed on cold pilger mills to produce strain hardened OCTG with defined strength properties. The tubulars are not annealed after cold forming and therefore retain a higher strength.

The cold pilgering line consists of a longitudinal cold rolling process with a very high cross-section reduction per pass, no process-related material losses, an excellent surface finish, an improved microstructure as well as close diameter and wall thickness tolerances. Ring dies and a tapered mandrel are used for forming during this process, which achieves cross-section reductions of more than 80% in a single working cycle for stainless steel and nickel alloys.

Figure 8 shows the principle of the cold pilgering process which consists of four main actions: The tube moves forward and is rotated while the ring dies move back and forth and rotates.

Fig 7 **60 MN extrusion press, Baosteel Group, China, tube O.D. 48-323mm**

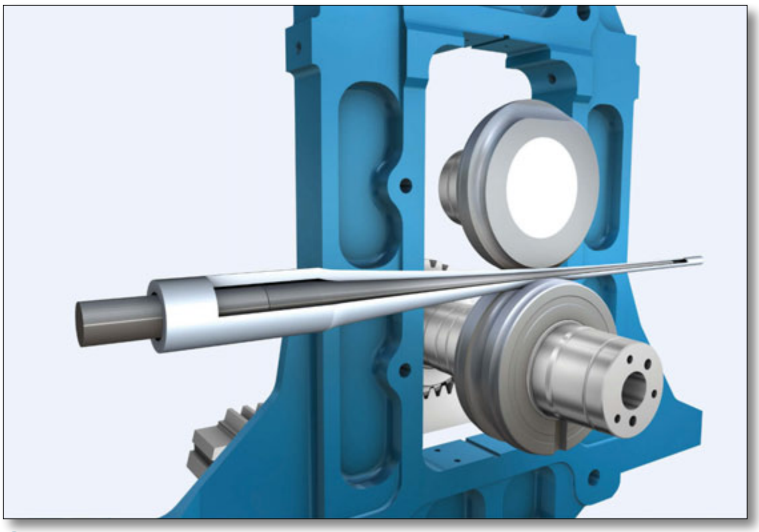

Fig 8 **Principle of the cold pilgering process**

The large cross-section reductions help to limit the process costs since intermediate process steps, such as degreasing, annealing, pickling, straightening and cutting that are needed, for example, between multiple cold drawing operations with decreasing cross-section reductions can be eliminated. The partial radial material flow during cold pilgering also helps to significantly reduce the wall thickness eccentricity of the mother tube. Experience has shown that the higher the initial eccentricity, the greater is the improvement in the eccentricity resulting from the cold pilgering process.

After cold pilgering, the outside and inside surfaces of the tubes are thoroughly degreased in special cleaning tanks (the degreasing facilities are produced by sub-contractors). The subsequent finishing steps are then as follows:

- Straightening
- Non-destructive testing (ultrasonic and eddy current)
- Cutting to length
- Mechanical water pressure testing
- Visual inspection/checking of the tube dimensions
- Marking/(thread cutting)/packing.

Other systems and machines are subcontracted according to the technical specifications of the SMS group.

SERVICE

After commissioning of the production lines, SMS group engineers will remain on site and help optimise production. At the request of the customer SMS can offer a wide variety of services, including continuous training of staff on the machines through to the optimisation of the maintenance system. SMS also carries out modernisations and plant expansions, such as replacement of components or increases in press force on the steel tube extrusion presses.

SUMMARY

The technical demands in the oil and gas industry are expected to lead to an increased demand for larger dimensioned, high-alloy steel tubes to allow larger quantities of oil and gas to be obtained even under difficult exploration conditions. The SMS group aims to meet these demands through supply of complete plants, modernisations and upgrades, use of modern information technologies in combination with the right maintenance strategy. The goal is to be able to offer extrusion presses for tube diameters up to 406mm (16in). MS

Dr. Ing. Hansjörg Hoppe is Sales Engineer and Dr. Ing. Hans Pelster is Technology Engineer in the Forging Plants Business Unit of the SMS group, Mönchengladbach, Germany.

CONTACT: thilo.sagermann@sms-group.com