DEVELOPMENT OF SEAMLESS STEEL TUBE MANUFACTURING TECHNOLOGIES

By

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I. Trend of Steel Tube Demand

The fast growth of steel tube demand — caused by the spread of municipal establishments, the development of manufacturing industries as well as the water and power supply, crude oil mining and other production branches — consequenced the high grade modernization of steel tube manufacturing technologies and equipments. It is characteristic for the expansion of seamless steel tube manufacture that taking the 1937-th weight production figures to 100, over 20 years the world's steel production grew to 230, the rolled steel production to 250, the seamless steel tube production to 270.

The diverse demand of manyfold utilization differentiated the tube assortment not even to sizes but to quality and finish too. The seamless steel tube products may be divided primarily according to quality requirements into four groups as follows.

a) First and by quantity greatest group contains commercial grade carbon steel tubes for water, oil and gas delivery.

b) The second group includes higher grade tubes for oil well casings and drill pipes. These are manufactured mostly of carbon steels and less proportion of low alloyed steels.

c) The third cathegory contains tube sorts meeting exacting tensile strength requirements, *e. g.* oil mining drill tubes, boiler tubes, antifriction race ways, made of sleeve — steel tubes, etcetera. These tubes are manufactured of high quality carbon steels or of alloyed steels. The demand for them is rapidly increasing.

d) At last we may designate to a seperate group the heat and corrosion resistant high alloyed tubes, often made of austenitic steels. Their demand is steadily increasing mostly on behalf of the power, chemical and food industries.

The seamless steel tubes of manyfold size, quality and finish are manufactured naturally with diverse technologies.

II. Up to Date Seamless Steel Tube Manufacturing Technologies

The seamless steel tube manufacturing technologies were adjusted to the trend of demands presenting themselves on the various markets in a wide variety of quality and amount.

All of the adopted technologies have a common characterizing feature. They all pierce a heavy walled short shell from the steel billet heated up to 1300° C. The finished tube is made on the extending machines in the same heating cycle.

Essentially two methods have spread for the piercing operation.

a) On certain tube mills the white glowing steel billets are pierced to a heavy walled raw tube on a pair of rolls or discs of oblique shaft arrangement.

b) On push benches and recently on intermittently working tube mills too, the glowing steel billet is formed to a heavy walled cup-like hollow shell by hydraulic presses.

Theoretically three kinds of processes were developed for the proceeding elongation of the pierced raw tube, resp. hollow shell.

a) Continuously elongating *e. g.* over a plug on two high stand mill of automatic Stiefel type tube rolling.

b) Intermittently elongating *e. g.* on Pilger stand with forging-rolling action over a mandrel.

c) Rigid ring die *e. g.* Erhardt type or roller die *e. g.* Csepel type tube elongating method.

In consequence of the rapid growth of steel tube demand and increased quality requirements the tube making processes were developed primarily towards higher productivity and within latter the attainable closest size tolerances. The auxiliary equipments went through basic changes too. Hand servicing became fully mechanized. The characteristics of the most spread technologies may be summed up as follows.

1. Continuous Steel Tube Mills

For manufacturing high quantity commercial grade tubes — in countries with great inland market — were developed the continuous steel tube mills, by linking more elongating stands after another. Its productivity surpasses that of all the seamless steel tube manufacturing equipments. So its yearly production *e. g.* of 50—100 mm O. D. tubes is appr. twice of the similarly high productivity automatic tube rolling mills. The building of continuous tube rolling mills requiring enormous investments may be allowed by countries having exceptionally high capacity markets.

2. Automatic Tube Rolling Mills

Its most acquainted variety is the Stiefer system automatic tube mill, rolling over a plug on two-high roll stand. It has to be fed with thoroughly homogeneous starting steel material rolled first on blooming, resp. on billet rolling mills. It is expedient to manufacture identical quality and sized tubes over long production periods, otherwise one has to give up its sole advantage of high productivity. Essentially the automatic tube rolling mill is also a productive mean for the mass production of simpler tube types to the high capacity markets. Its investment costs are relatively high, the price of its starting material is higher in consequence of blooming, the choice of finished products is close. The unevenness of the inner tube surface may be eliminated but by costly tools. In the last decades the similarly rapidly developing, resp. spreading processes, namely those producing tubes of steel band by electric welding raised close competition for the continuous and automatic tube rolling mills in the high quantity commercial grade tubes.

3. Intermittently Elongating Tube Rolling Mills

Its classic representative is the Mannesmann-Pilger — designated in the following with M-P —, resp. its modernized variety the Elongating-Pilger — designated in the following with E-P — process. While thi- technology offers high production flexibility combined with wide choice of finished products and low investment costs, it is advantageous for smaller or medium or developing countries. In great industrial countries this process is advantageous for the manufacture of certain high quality but less quantity needed tube sorts. Because of these facts we are going to deal with the development of this method a bit more in detail in the followings.

As it is known the original M-P process starts from round cast ingot and makes a heavy walled raw tube on the oblique axed rolls of the piercing stand. Afterwards the raw tube is intermittently elongated into a light walled tube on the active surfaces of the Pilger stand's two rolls. Its advantage is that high quality tube may be obtained from ingots. Its disadvantage is that in case of manufacturing certain tube types, *e. g.* high pressure bioler tubes, the outer mantle surface of the round ingot has to be scraped. On Fig. 1 the M-P technology's steel ingot, raw tube and elongated finished tube are shown.

At the E-P technology developed from the former it is expedient to start from square shaped continuously cast steel ingot. Namely the square shaped continuous steel casting may be more easily and cheaply solved than the round shaped one. Moreover at the square shaped ingots the danger of surface cracks is smaller. The heated up ingot is formed into a cup shaped hollow cylinder by hydraulic presses. The so obtained glowing hollow shell is elongated to a heavy walled tube and its closed bottom pierced on a revolving mandrel between the obliquely set rolls of the tube elongating stand. The further elongation is made on Pilger stands similarly to the original process.

On Fig. 2 we may see the various interstage products of the E-P process.

The most important results obtained by the modernization may be summed up as follows.

a) The square shaped ingot which may be used instead of the round one is more easily attainable, more reliable and means a cheaper starting material.

b) As the consequence of the concentric piercing of the starting steel ingot and the centre adjusting-straightening action of the elongating stand's oblique roll pair, the deviations in wall thickness tolerances were reduced in both directions by appr. 20%.

c) The smoothness of tube walls, especially on the inner surface was further refined. The material of the elongated medium walled tubes are more easily moulded, thus the steel's inner structure will be denser.

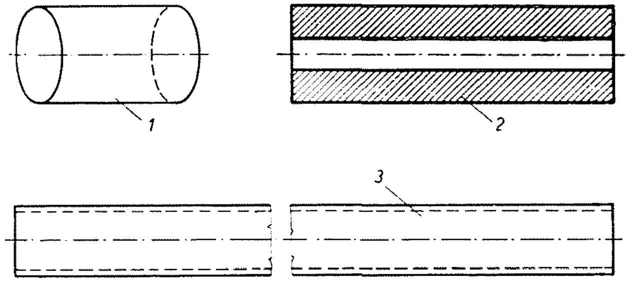

Fig. 1. The inter-stage products of the M-P process
1. Starting steel ingot
2. Pierced raw tube
3. Finished tube

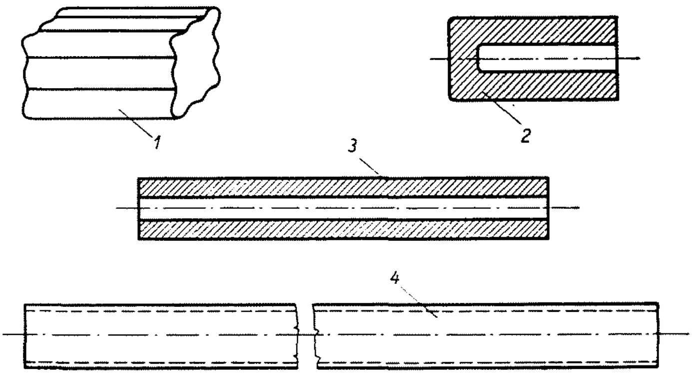

Fig. 2. The inter-stage products of the E-P process
1. Sized and pierced hollow shell
2. Elongated tube
3. Finished tube

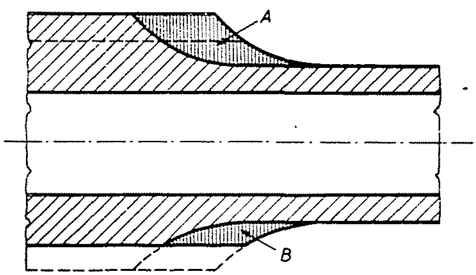

Fig. 3. Material to be elongated during a single feed operation by the Pilger mill
A) At the M-P process
B) At the E-P process

d) Because the Pilger rolls get by more lighter walled tubes for further drawing from the elongating stand than from the Mannesmann piercing stand at the original method, the speed of the Pilger rolls and the speed of the feeding mandrel could be increased. By these measures noteworthy raise of productivity could be attained. Productivity could be raised on medium duty Pilger mills appr. by 70%, on high duty Pilger mills appr. by 100%.

Fig. 3. shows the difference between the volumes of material to be elongated during one feed stroke in case of M-P and E-P processes.

By such means the high productivity, up-to-date E-P process, resp. the Elongator-Pilger mills realizing latter, manufacturing high quality tubes starting from a cheap material, became competitive and requested for, on the world market.

On Fig. 4. the photograph of an Elongating Mill Stand is shown.

4. With Dies Elongating Push Benches

Its most modern solution is the Csepel type push bench elongating with roller dies. The push bench starts from round or square billets or ingots. These are sized, resp. pierced by hydraulic presses similarly to the B-P process, to a closed bottom hollow shell. The glowing pierced hollow shell is pushed through roller dies arranged behind each other with gradually decreasing inner diameter. The inner diameter of the last stand's die gives the required outer diameter of the finished tube. The inner diameter of the tube is set by the diameter of the push mandrel. Recently in order to boost production and to obtain closer wall thickness tolerances an elongating roll stand — working with oblique roll pair — was inserted into the flow technology following the sizing and piercing operations. The cup like glowing shell is elongated on its revolving mandrel, and hence it gets onto the Push Bench to

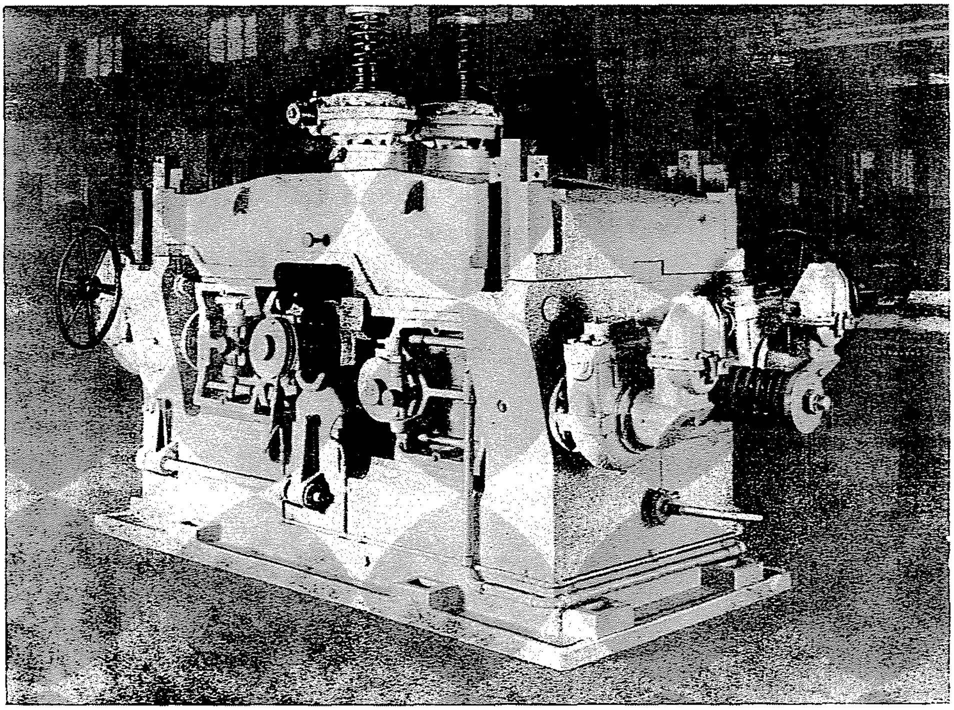

Fig. 4. Elongating mill stand of the B-P technology's production line. Photograph taken in the DIMÁVAG Machine Works, Hungary

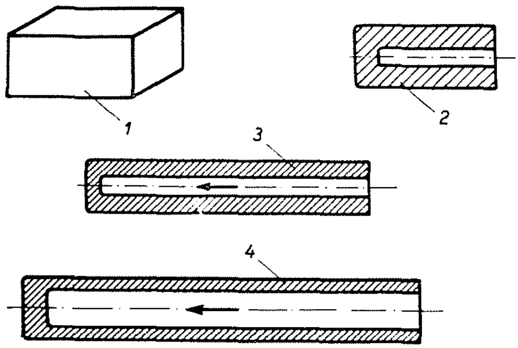

Fig. 5. The inter-stage products of the modernized Push Bench process
1. Steel billet, 2. Hollow shell, 3. Elongated shell, 4. Finished tube

be pushed through its roller dies thus obtaining its permanent and finishing elongation.

Fig. 5. shows the inter-stage products of this modernized technology.

The results of modernization: wall thickness tolerance reduction by 25%, productivity boost by 70—90%. The surplus unique advantage of the Csepel type roller die push bench is that it is excellently adequate for the manufacture of high alloyed corrosion and heat resistant tubes in the range of 50—200 mm diameters.

III. Main Characteristics of Steel Tubes Produced with Various Kinds of Technologies

We compare in the following some characteristics of tubes produced on continuous automatic and on intermittently working E-P tube mills.

A) *Surface Smoothness*

It is known that the corrosion resistance and tensile strength of steels depends of surface smoothness by a high degree. Among the hot rolling processes the smoothest outer and inner wall surfaces may be obtained by the Pilger elongating process. Namely each tube section gets twice between the elongating and smoothing gorge of the Pilger rolls, therefore the tube wall is worked to a smooth finish. The E-P technology's elongating operation creates more favourable conditions especially in respect of inner tube surface smoothness.

The endurance limit is extremely important in respect of life expectancy and reliability among others at oil well drill pipes or at pipings working with elevated temperatures and high inner pressures. Examining for

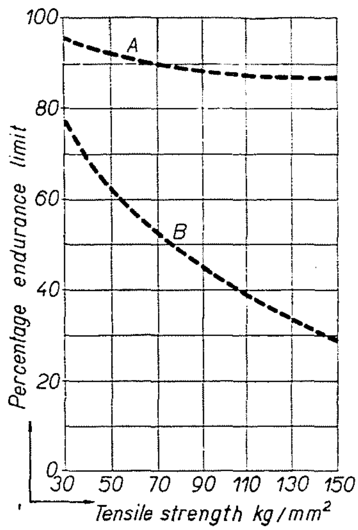

Fig. 6. The percentage decrease of endurance limit caused by tube wall unevenness versus increasing tensile strength

instance the endurance limit of drill pipes versus tensile strength it was experienced that with increasing the tensile strength, the endurance limit rapidly decreases because of the unevenness of tube wall surfaces.

On Fig. 6 The curve designated with A shows the endurance limit decrease versus tensile strength increase of an outside and inside polished tube. Curve B shows the endurance limit decrease of a hot rolled, on automatic mills manufactured tube of generally much more uneven surfaces. The smooth surfaced pilgerized tube's similar characteristic lies between the curves A and B. This question comes more and more into prominence, because by the increase of oil well depths the endurance limit of the drill pipe's steel material has to be raised simultaneously, too. But similar requirements arise on other fields of applications, too.

B) *Micro Structure of Steel Tube Walls*

The inner fibre arrangement of tubes, intermittently elongated on Pilger mills is much more advantageous compared to those made on automatic rolling mills. For illustrating this, we introduce the principles of intermittent and continuous tube elongation on Fig. 7, besides each other.

At the continuous automatic tube rolling mills (See Fig. 7, Sketch A) the inhomogenities of the steel's crystal structure are prolated on the whole parallel to each other in consequence of the high degree uniform elongation. The material attests fibrous structure character. (See Fig. 7, Sketch A). On the other hand it is known, that the fibrous texture increases the notch sensitivity, the dangerousness of notches and scores. In crosswise deteriorate the ductility, elongation, contraction and Charpy impact values. For instance according to Rössing's tests the crosswise fatigue limit of fibrous stells is by 15—29% lower than lengthwise.

The Pilger process not only elongates the steel but moulds it, too, therefore the inhomogenities of the steel's crystal texture are prolated more in an undulated form and are felted irregularly in all directions. (See Fig. 8, Sketch B). Such tube is more resistive against internal and external stresses than that of a fibrous texture one. The compactness of the pilgerized tube's materia

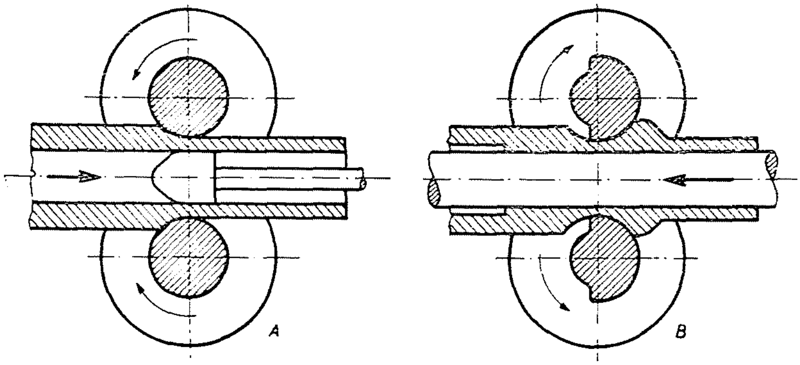

Fig. 7. Elongation of tube wall material:
A) On continuous, automatic tube mill
B) On intermittently working Pilger mill

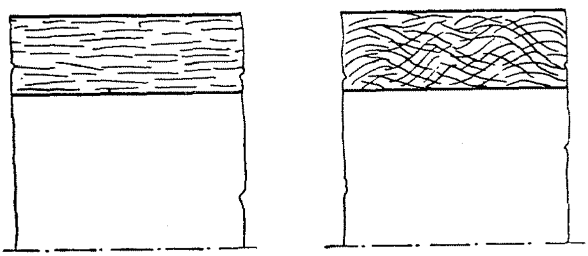

Fig. 8. Fibre arrangement of finished elongated tube walls
A) Sketch of continuously elongated fibrous texture tube wall;
B) Sketch of on Pilger mills elongated felted texture tube wall

shows relationship with steels compacted by multidirectional forging operation. This latter characteristic is very advantageous for tube structures exposed to repetitive high stresses.

Summing up the precedings, we may realize that the up-to-date E-P process demonstrates such outstanding results, that even in great industrial countries where the commercial mass products are manufactured on automatic tube mills, the up-to-date Elongator-Pilger process may be advantageously applied for the production of certain high quality tube sorts *e. g.* drill pipes. These are proved by the last years' tube mill investments and reconstructions.

IV. Ratio of Tube Mill Capacity and Cost

It is not indifferent for the investor the ratio of the tube mill's capacity, working range, corresponding first cost, respectively investment cost. Taking for comparison's purpose the weight of the Elongator-Push Bench Mill, its mean world market price, and its mean yearly tonnage production to a base 100; we formed indexes from the same data of several equipments of same technological completeness and show them in Table 1.

If we take into account beyond the table's data that the higher weight and dimensioned equipments require obviously higher building and additional investment costs, it may be stated that the push benches dispose with the most favourable economic indexes in consequence of their relatively low investment costs and high productivity. However, the flexible operation and high quality of their tube products secure competitiveness even priority for the Elongator-Pilger tube mills besides the automatic tube mills. The adoption of up-to-date E-P mill, that starts directly from ingots, has high productivity, offers wide tube assortment, is specially advantageous for developing countries. However, as mentioned before, it is advantageously applicable in industrial countries too for the manufacture of high quality carbon steel tubes.

Table 1

Type of equipment	Max. tube diameter in mms	The technological equipment's		Yearly output index
		weight index	price index	
Elongator-Push Bench	130	100	10s	100
Elongator-Pilger Mills	220	290	250	106
	320	430	370	244
Automatic two-high-stand tube mills	140	400	270	165
	400	1300	720	390*

* Esteemed value

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