'TECHNOLOGY OF STEEL 'MBE MAIUM

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I. INIRODUCTION

The manufacture of steel tubes which are used for a wide range of applications, involves large variety of production processes. Depending upon the end use and economics, different processes used for steel tube making can be classified broadly into two distinct groups:

(a) Welded, and (b) Seamless

Under the category of welded tubes, the two main processes available are (i) Electric Resistance Welding (ERW/HFIW) and (ii) Furnace Butt Welding (HFW/Fretz Moon). Electric Resistance Welded tubes are manufactured using direct or high frequency induced current in formed circular hot or cold rolled steel. strips. This process has also undergone remarkable advancement in the technology in terms of both production and quality, in the recent past.

Furnace Butt Welding is effected by pressure welding, where the entire strip is heated in a tunnel furnace and the edges are further heated to a temperature near fusion point and then pressed together. This process is also called as Fretz Moon Process.

Under the category of seamless process, the three main stages involved are piercing, elongation and sizing/stretch reducing. Over the years considerable developments have taken place in the area of seamless tube making to improve the process with respect to yield, wall thickness tolerance, diameter to thickness ratio and towards manufacturing tubes of larger variety of steel grades.

2. PROCESSES AVAILABLE AND THEIR EM) USE

Welded and seamless tubes of various categories are produced through different manufacturing processes. Processes in use, their size range and end uses can be summarised in the following Table:

Tube category	Process	Size range	End use	Remarks
Welded:				
(a) Furnace Butt Welded	Fretz Moon	10 mm NB to 100 mm NB	Low pressure water, air and gas conveyance	
(b) ERW (General)	High frequency induction welding	20 mm OD to 660 mm OD	Water and gas conveyance, structurals, casing line pipe, process industry	
(c) ERW (Precision)		12.70 mm OD to 76.20 mm OD	Boiler, air heater, cycle, automobile, mechanical	
Seamless:	Mandrel Mill	340 mm max OD*	Line pipe, casing, boiler, mechanical, tubing, process industry	Suitable for capacity upto 500,000 per annun
	Plug Mill	406 mm max OD*	Mechanical, casing, process industry	At present suitable for diameter over 150 mm only
	Push Bench	178 mm max OD*	Line pipe, boiler, casing, process industry	

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Tube category	Process	Size range	End use	Remarks
	Extrusion	260 mm max OD*	Special	Suitable for alloy steel due to high cost of production
	Pilger Mill	700 mm max OD*	Line pipe, casing, boiler, mechanical, tubing, process industry	At present suitable for 325 mm OD and above
	Asset Mill	260 mm max OD*	Casing, bearing, mechanical, line pipe.	
	Discher Mill	245 mm max OD*	Casing, bearing, boiler, line pipe, mechanical, process industry	
	Planetary Mill	245 mm max OD*	Casing, mechanical, bearing, line pipe, process industry	Yet to be fully established

NOTE: * OD of the mother tubes, thus produced from different processes are further brought down by using Sizing/Stretch Reducing Mill. Minimum OD is about 20 mm depending on the mother tube OD and the Stretch Reducing Mill.

3. PROCESS DESCRIPTION

3.1 nirnace Butt Welding

This process is characterised by pressure forge welding of edges of low carbon rimming steel strip by gradually heating the entire section of strip in a tunnel furnace to 1300°C and subsequently forge welding of edges by passing through welding rolls. The edge temperature before forge welding is raised to the level of 1350°C by blowing oxygen just before welding in order to induce sufficient weld penetration. During the later passes, the weld is consolidated and tubes are finally sized at about 850/900^{0}C and cooled in air followed by water spray to nearing room temperature. The process has some inherent advantages like, excellent manipulation characteristics, smooth bore and uniform homogenised metallurgical structure throughout the tube section. However, the process has some limitations as it usually requires single width low carbon rimming steel strip. The tubes, thus, produced are essentially of lower strength and are conventionally used for low pressure fluid flow applications. Fig.1 shows the process flow sequence of a Fretz Moon Process.

3.2 Electric Resistance Welding (ERW/HFIW)

The ERW process involves a complex system of mutually interacting factors in which a **flat strip** is uncoiled and passed through a series of cold forming rolls and welded finally to form a circular or square or rectangular section tube. ERW tubes are manufactured by High Frequency Induction Welding (HFIW). The hot rolled strip is first (pickled and cold rolled in case of precision tubes) slit and resultant strip then enters the ERW Mill, for tube making. Following are the basic process steps involved in the manufacture of ERW tubes:

UNOOLLIht OF STRIP

STRIP 'ID STRIP WELDING : Strip edges are first flattened on a leveller and the ends are cut by up-cut shear. Coil ends are then welded to make feeding of strip continuous.

STRIPPING The extra metal formed after welding is removed by stripper, particularly in case of precision welded tubes.

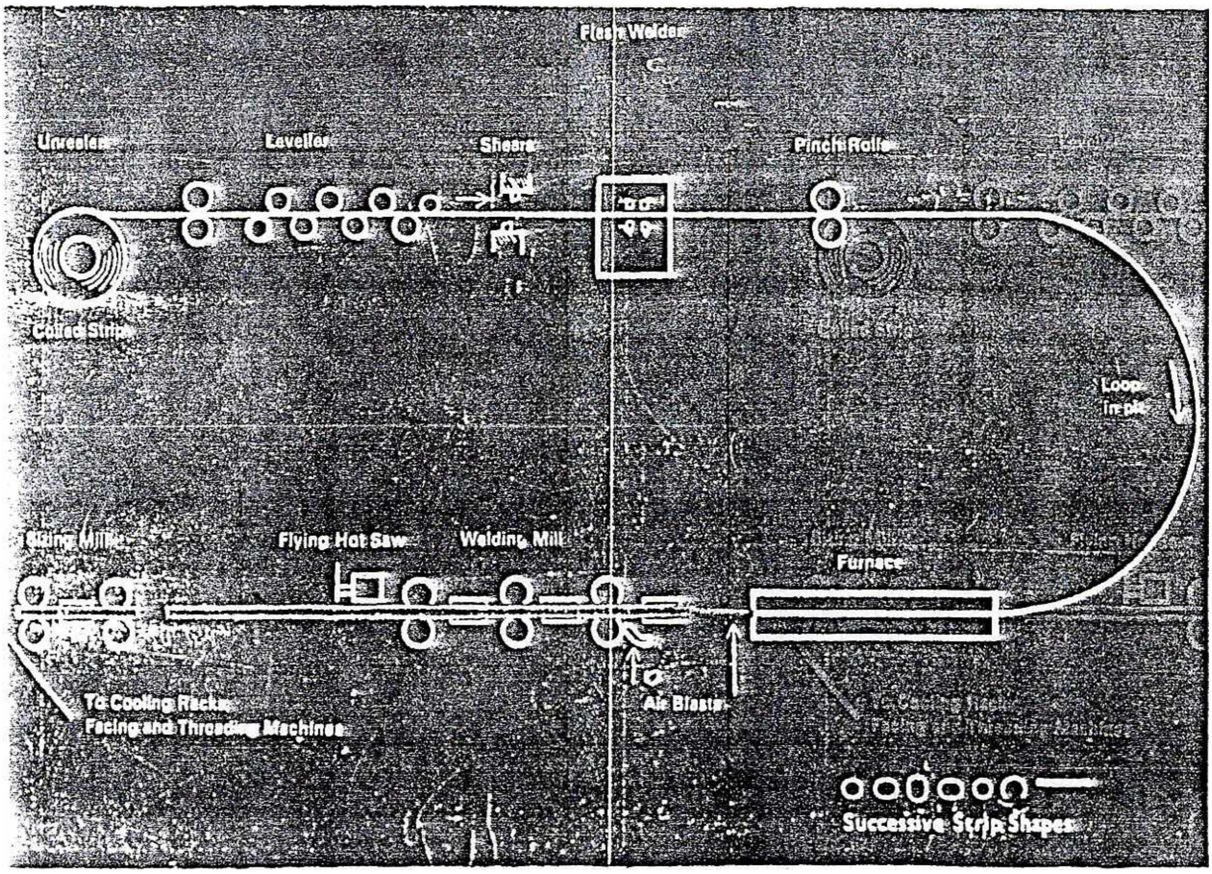

Fig.1 Fretz Moon Process

LOOPIIC A large loop is formed between the strip welder and the forming mill to operate continuously even when the strip movement is stopped during welding. The strip is fed to the forming mill either through conventional coil pit or coil accumulator.

EDGE 1RDMING The strip edges are trimmed to the exact width required and to ensure the cleanest possible surface for welding in case of coils with unslit edges.

FORMING Forming of strip is performed through break-down rolls and fin pass rolls.

WELDING The'abutting edges are welded together electrically. An induction coil surrounds the tube at a distance down stream the forming rolls. A high frequency current is induced into the strip and flows along the edges of the strip between the point where the edges meet and the point of application of the induction current. It establishes a complete circuit by flowing around the edges of the open 'V' up to the point where metal to metal contact is first made. At the weld point the squeeze roll assembly presses the edges together with a controlled pressure resulting in welding of edges. It is shown in Fig.2.

BEAD TRIMMING After welding, beads are formed inside and outside the tube along the line of the weld. The outside bead is immediately removed, while the tube is fairly hot, with the help of triming tools. Inside bead is also removed, where ever required, with the help of internal bead trimmer.

SIZING Tube passes through a series of sizing rolls to ensure an accurate outside diameter.

N.D.T The tube passes through an on-line NDT machine (Eddy Current Testing Machine) to detect surface flaws and weld flaws.

Whenever square or rectangular shape is required, round tube is passed through a set of two or three turks head roll stands.

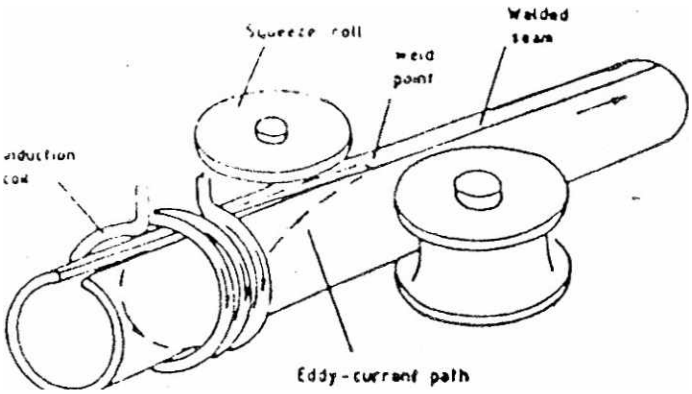

Fig. 2. Eddy-current path in high-frequency induction welding of tubular products

CUTTING : *As* the tube emerges from the sizing stands, sliding saw or shear cuts it to the required length.

NORMALISIIC : gibes for comparatively higher pressure and temperature use and special applications are normalised in controlled atmosphere to homogenise the grain structure and to relieve the residual stresses.

FINISHING Thbes are fdrther tested and processed through different finishing operations depending on end use.

Figure 3 shows the process flow sequence of a typical ERW Mill.

3.3 **Seamless**

The basic process steps involved in the manufacturing of seamless tube are explained below:

HEATING FEEDWOCK TO 1300°C : Feedstocks, unit length solid rounds or gothics, are charged into the Rotary Hearth Furnace and gradually heated to a temperature of 1300°C.

PIERCING INTO A SHELL : In general, three types of piercing processes are used in tube rolling mills depending on shape of the feedstock, the material to be pierced and wall thickness tolerances. These are:

(a) Piericing press: In the piercing press, the feedstock is introduced into a vertical or horizontal ccriainer, to be subsequently pierced by a mandrel. This produces a round bottle with a solid end which is normally elongated and pierced throuth on a rotary elongator. The metal deformation takes place under compressive stresses and therefore, can be considered as a very gentle racerial treatment. This makes the piercing press suitable for the forming of material that have high forming resistance such

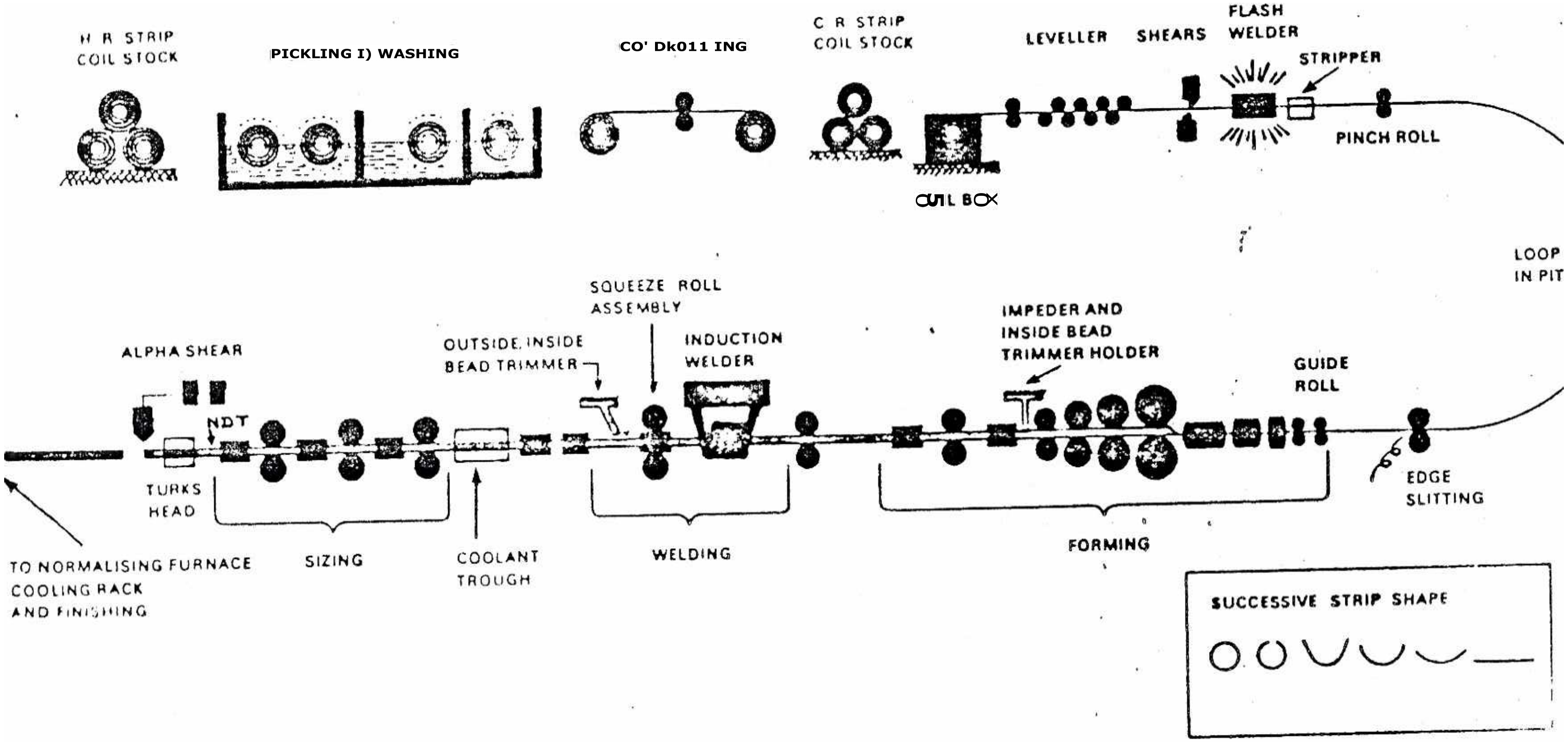

FIG.3 Principles of ERW tubemaking process

as in the case of higher alloy material. But the advantages for the metal forming offered by the piercing press can be realised only at the cost of lower output and reduced flexibility. because from one feedstock dimension, only one size of shell can be produced. A major drawback is insufficient guidance of the piercing mandrel. Even a marginal lack of homogenity due to temperature variations in the product can cause the mandrel to move off-centre, thus producing unacceptable eccentricity in the shell. This process also restricts the shell length. Fig.4 shows this piercing process.

(b) Press piercing mill: In the press piercing mill, the feedstock normally of gothic section is guided and pushed into a two driven roll one stand mill, and- elongation takes place over a fixed piercing point held by a mandrel. Just as with a piercing press, with a press piercing mill there is also very little flexibility. With this process, shell length can be increased and eccentricity can be reduced as compared to Piercing Press. Fig.5 shows the operation of press piercing mill.

(c) Cross roll piercing: Only solid round feedstocks are suitable for cross-roll piercing. The cross roll piercing mill usually has two specially shaped work rolls, driven in the same direction with their axes set at an angle to the horizontal centre line of the stock. The stock is gripped in the tapered entry section of the rolls and rolled into a shell in a helical movement over a mandrel. Main advantages of this process are better concentricity, dimensional flexibility and longer shell lengths. Fig.6 shows the operation of Cross Roll Piercers.

ELONGATION OF A SHEEL INTO A MOTHER TUBE

The pierced shell is further elongated into a mother tube by using different elongation mills, like Pilger Mill, Plug Mill, Push Bench, Extrusion, Asset Mill, Planetary Mill, Diescher Mill and Mandrel Mill.

(a) **Pilger mill: It** is a versatile mill with the ability to change diameter and thickness with relative ease. The tube is rolled in a reciprocating motion in single two roll stand over a mandrel where elongations of the order of 13:1 can be achieved.

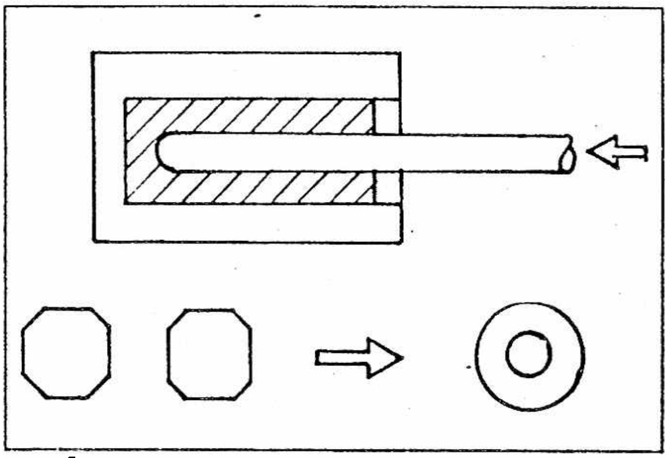

Fig. **4** : Piercing press

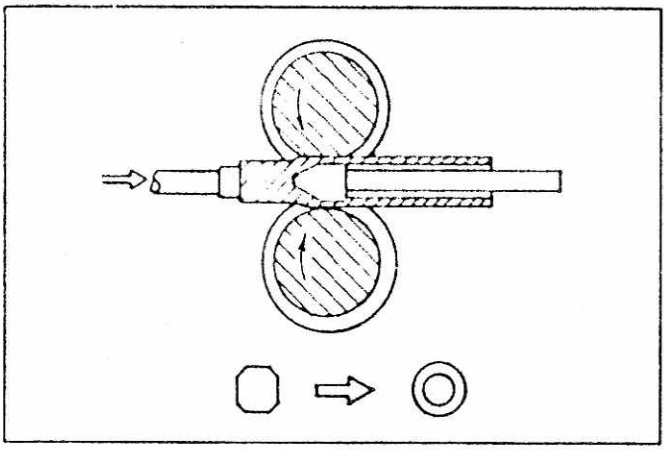

Fig. 5 : Press piercing mill

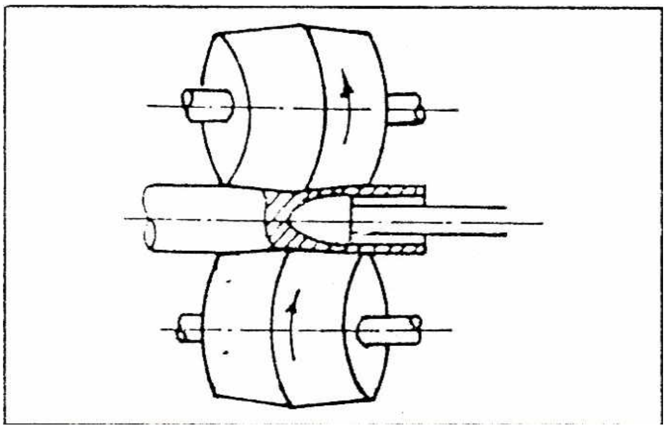

Fig. 6 : Cross mil pierces

The process is slow and labour intensive and prone to large thickness variations. Yields in the pilger are also much lower co7,pared to that of other mills. However, for size above 325 mm O.D the pilger continues to be the most economi-. cal process. Fig.7 shows the operation of a Pilger Mill.

(b) Plug mill: The operation consists of rolling an elongated shell in a single two roll stand over a plug which is supported by a mandrel from one end and mounted between the grooves of the rolls to form an annulus through which the hollow is formed. The plug mill is followed by two reelers before entering the sizing or reducing mill. The plug mill in itself is a poor elongator and a maximum elongation ratio 1:1.8 only can be achieved. Hence, both the cross roll piericing and elongating stages become important for large diameter Plug Mills. Fig.8 shows a plug mill.

(c) The push bench: In this process, a pierced bottle having •a solid end is threaded on to a mandrel and thrust into a series of idler roller dies and fixed ring dies for reducing thickness and elongating the workpiece. The process is explained in the Fig.9.

The process because of no cross rolling, has limitations of high eccentricity. In recent developments, a rotary elongator has been introduced between the piercing press and push bench stages to reduce thickness variation. More recently there has been further development in this process where a solid round is pierced on a cross-roll piercer and one end is almost closed on a crimping press before threading on the mandrel pushing the shell into the Push Bench. This process is called CPE Process.

(d) Assel mill: The Assel Mill as shown in Fig.10 involves cross rolling of a shell produced by a high elongation rotary piercer. The Assel Mill is equipped with three rolls, set at an angle to the mill pass line and rotate about their axes. A hollow shell from piercer is mounted with a mandrel bar and fed into the rolls. A hump on the rolls then produces a sudden reduction in O.D and wall thickness of the pierced shell. The main disadvantage of the

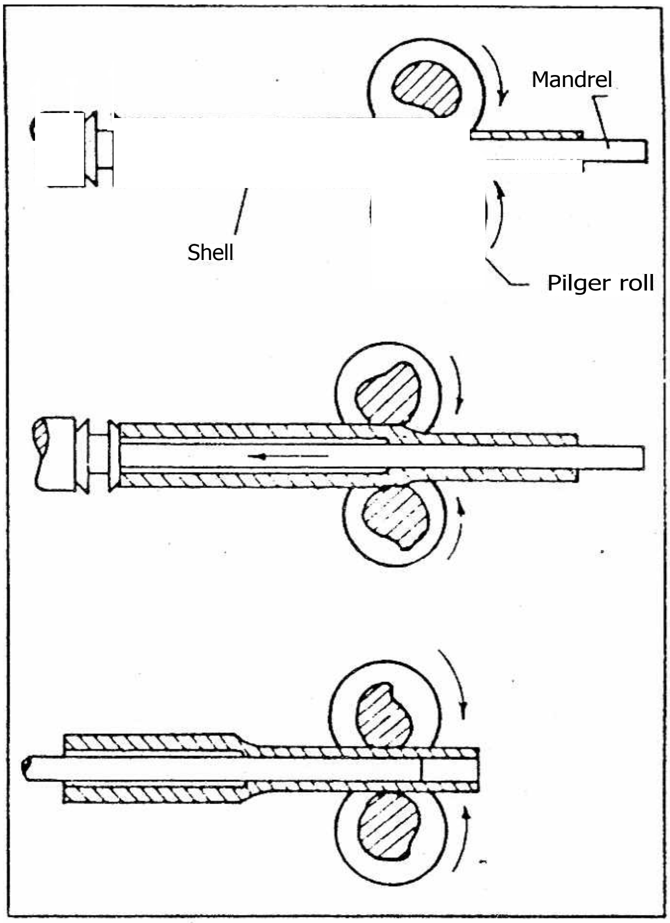

Fig. 7 : Pilgcr process

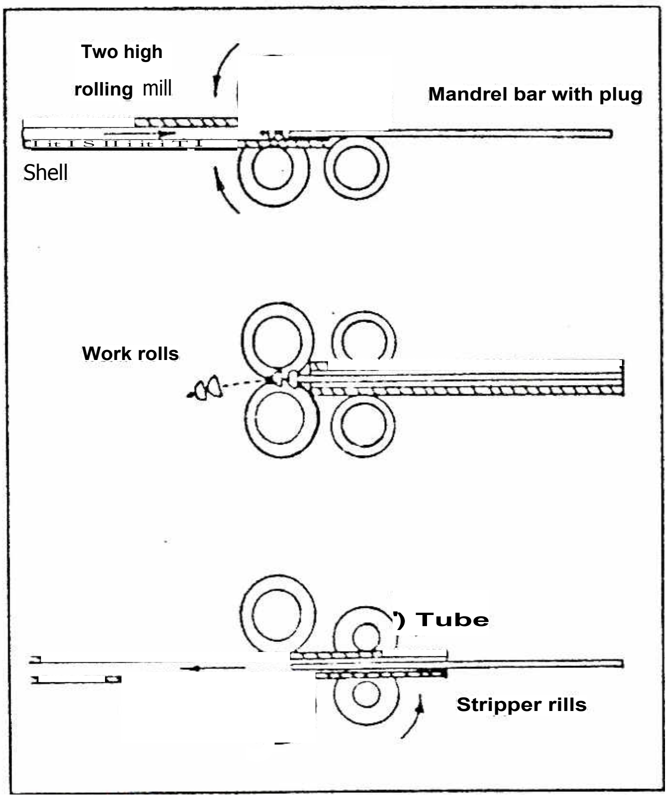

Fig. 8 : Plug mill

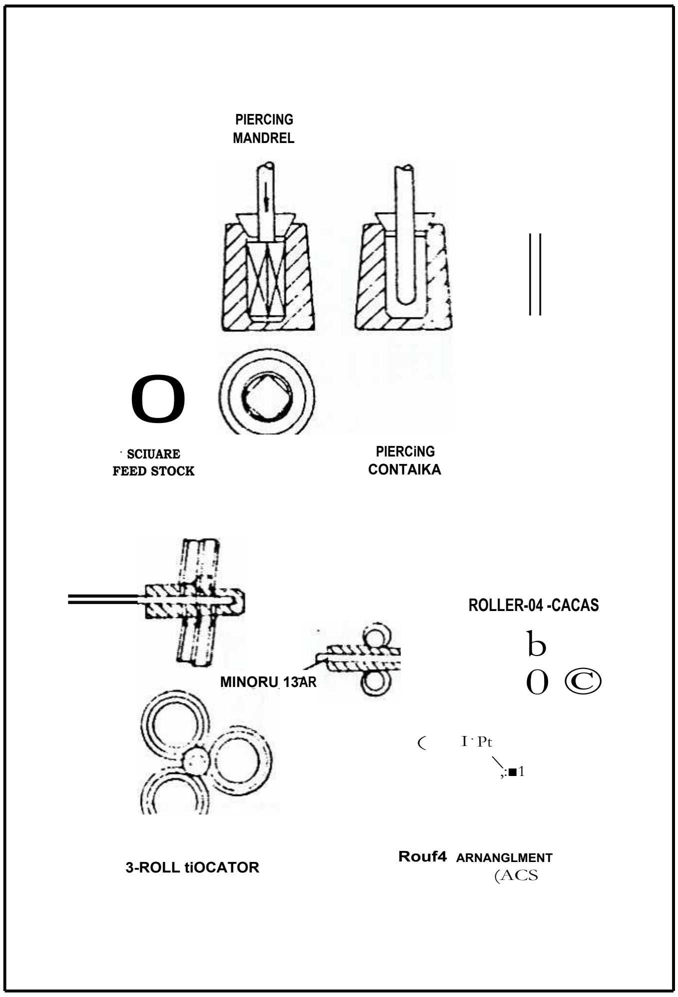

Fig. 9 Push bench process

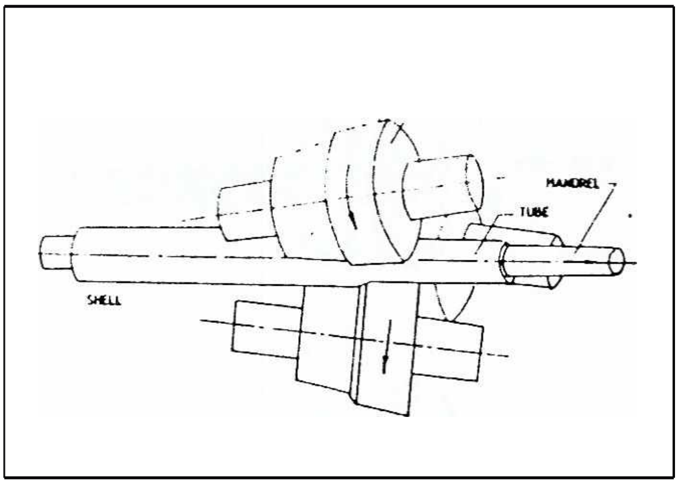

Fig. 10 : The *Assel mill*

conventional Assel Mill is in its inability to produce D/t ratios greater than 12 without triangulated ends. Also, severe stresses on outer fiber of tubes makes it unsuitable for the production of boiler tubes. However, recently improvements have been made to increase D/t ratio upto 35. The requirement of steel quality is very stringent.

(e) The extrusion process: The extrusion process, horizontal or vertical, uses mechanical or hydraulic power to push a hollow shell through the orifice of a die over a short mandrel as illustrated in Fig.11. The process is characterised by high elongation over a short distance. Both horizontal and vertical presses are capable of accepting continuously cast material. However, since the vertical system can be operated effectively with oil graphite lubricant, it is suited for low carbon, low alloy pipe production. A decline in the use of this process has primarily come about because of some disadvantages (i) high eccentricity (ii) low yields because of high crops end losses, and (iii) high tooling and lubrication costs. However, this process is still in use for the production of stainless and other high alloy steels.

(f) Continuous mandrel mill: The continuous mandrel mill consists of seven or eight in line, driven two roll stands. Each roll has a semi-circular groove on its circumference such that when these are paired, they form a circular pass through which the workpiece and mandrel have to move. Fig.12 shows a basic continuous mandrel mill. Elongation of the order of 4 or 5:1 can be achieved.

(g) Planetary mill: In the Planetary Mill, three work rolls rotate about their own axes and are housed in a cage which also rotates about the mill axis. The three conical rolls are inclined at about 60 degrees to the mill axis to produce a converging shaping zone. The hollow shell from the piercer is mounted on a retained mandrel and fed into the conical shaping zone formed by the three rolls. The main advantage of this mill is that a wide range of alloy steel materials can be rolled. However, this process

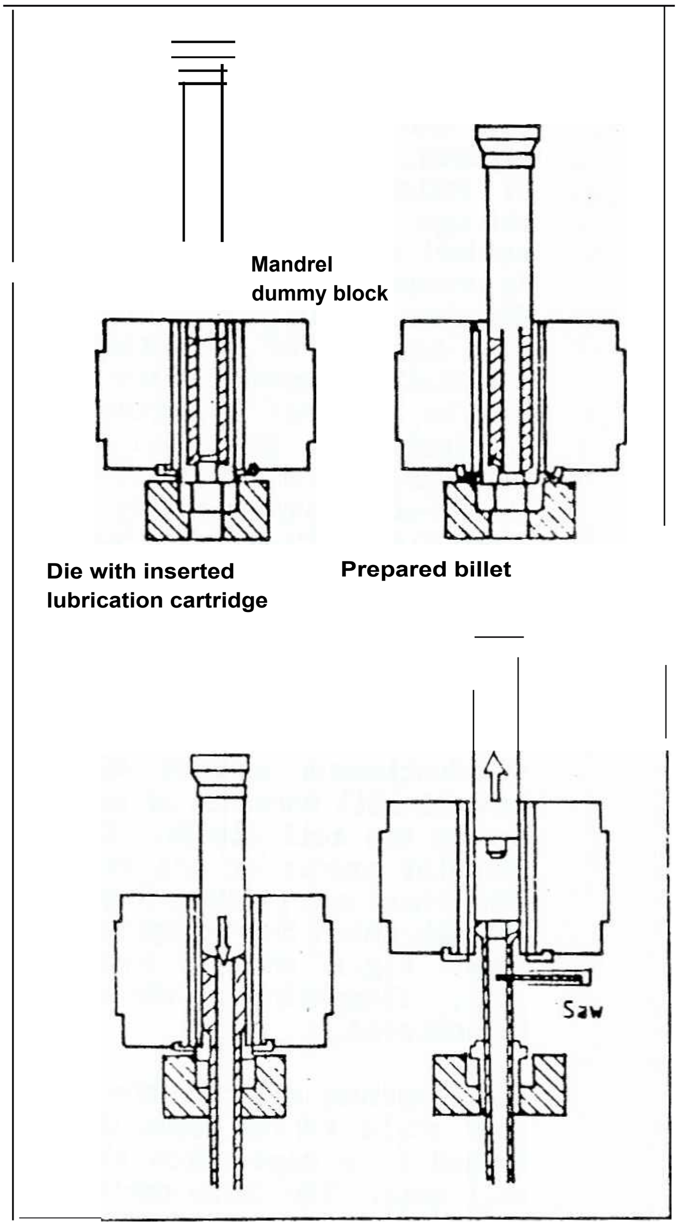

Fig. 11 **Extrusion press**

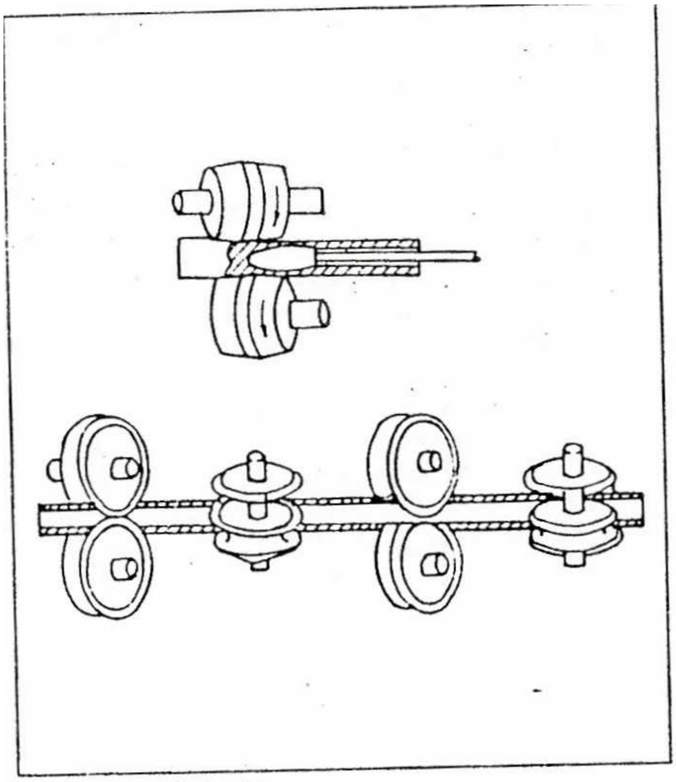

Fig. 12.: Mandrcl mill

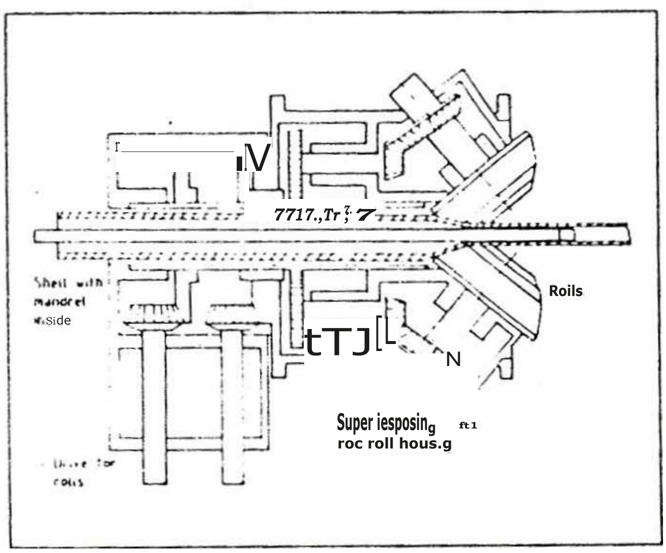

Fig. 13 Three roll planetary mill

has not yet been widely accepted because of compexity of the mill. Fig.13 shows the Planetary Mill.

SIZING/REDUCING TO FINAL SIZF.

• Ribes after elongating operation is either sized on 3 to 5 stands sizing mill or stretch reduced on 15 to 24 stands mill. In stretch reducing process, a mother tube is rolled at a temperature of about 850 to 900°C. In a series of roll passes of stretch reducing mills and reduced to the final tube diameter while simultaneously obtaining the desired wall thickness by selectively increasing the roll speeds from stand to stand, thus determining the exact amount of longitudinal stretch on the tube. Sizing and Stretch Reducing Mills (SRNs) are used down stream to any of the elongation mills as described above.

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STRAIGHTENING

It is normally done on a cross-roll straightener.

FINISHING

TUbes are further tested and processed through different finishing operations depending on end use.

Welded

a) ERW/HFIW

Application	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Mechanical Achievable As welded U.T.S	Y.S	[illegible]
Boiler/Automobile/ Mechanical/Cycle	0.09/0.14	0.40/0.55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.09/0.14	0.50/0.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Automobile/Mechanical	0.19/0.23	0.40/0.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Application	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Y.S /mm sq	[illegible]
[illegible] air and gas [illegible] ance purpose	[illegible]	0.35/	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-do-	[illegible]	0.35/	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Application	Alloying elements						Mechanical properties achievable in HFS normalised condition		
	[illegible]	[illegible]	[illegible]	% Si	% C.EQ	And other elements	Y.S kg/mm sq	U.T.S kg/mm sq	% Elongation (GL-5.65/A) Min.
[illegible]		0.80/1.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1.50/1.85	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.11/0.16	0.70/1.00	0.030 max	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.15/0.20	1.10/1.30	0.030 max	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
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5. COMPARATIVE EVALUATION OF WELDED AND SEAMLESS TUBES

Parameter/characteristics	Seamless	Welded
a) Raw material	Solid round/gothics	Strip
b) Plant yield	Low	High
c) Diameter to thickness ratio	4-35	7-65
d) Thickness of tube	Medium to high	Low to medium
e) Thickness tolerance	Wide	Close
f) Pressure rating	High to very high (upto 10,000 psi)	Not very high
g) Strength of pipe	High	Comparatively low
h) Steel grade	Carbon steel to alloy steel	Restricted by weldability (C.E = 0.55% max)
i) Cost of production	High	Low
j) Cost of installation	High	Low

6. CONCLUSION

Primarily processes available for steel tube making are of two distinct categories -- viz. welded tube using strips and seamless tube using solid raw stock. Both have their characteristical advantages and limitations. The choice of technology depends on the specific end use. For certain application seamless and welded both can be considered.