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Why surface treatment is must for cold drawing mild steel tubes

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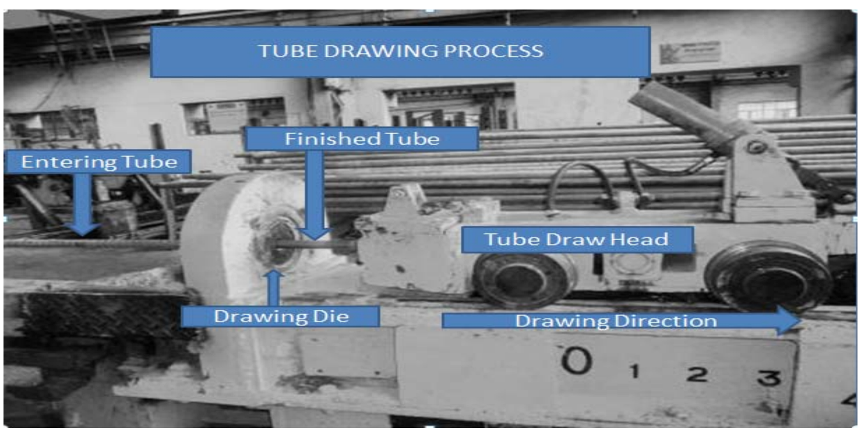
Abstract: *Cold Draw Welded (CDW) tubes find a wide array of applications in the automobile industry. Electric Resistance Welded (ERW) tubes are surface treated with certain chemicals to make them eligible for cold drawing. The surface treatment is a time consuming process. Efforts have been directed to eliminate it altogether or at least to reduce its cycle time. We have assiduously conducted certain trials to establish the nature and character of the surface treatment. With the knowledge thus generated, we have, in our capacity, attempted to analyze why surface treatment is sine qua non to cold draw.*

Keywords: Surface treatment, CDW, Pilger process, Cold Draw, Phosphating

1. Introduction to metal drawing process- Tube drawing is a cold working process**.** ERW tubes are annealed or normalized for homogenization in its microstructure, subsequently this is surface treated with various chemicals to make it suitable for further cold drawing. One end of the tubes is swaged so that it may pass through the die. The tubes are then pulled through the die and plug, which reduces its cross sectional area. Since, volume remains a constant quantity; the length of the tube gets increased.



Tube drawing process

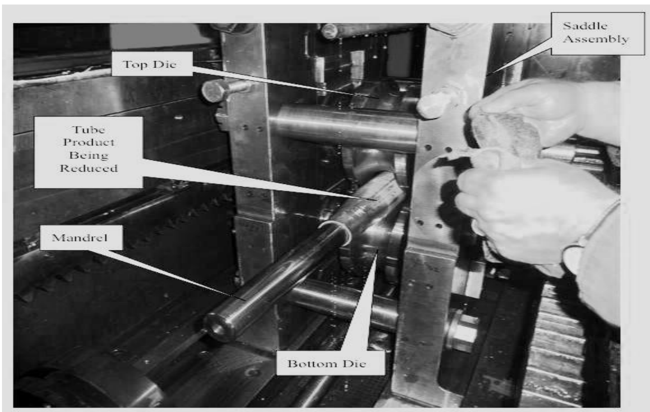
Die used in tube drawing process

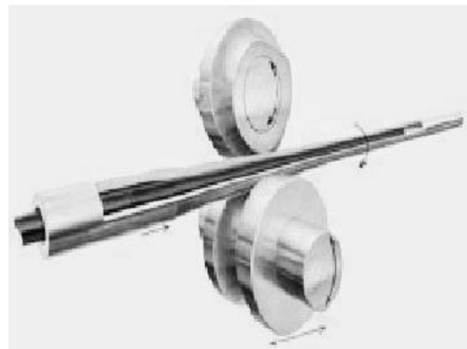
Factors which affect the tube drawing:

1. **Speed and time** –the speed of the tube drawing process is high
2. **Friction** –there is friction b/w metal to metal contact (co-efficient of friction for steel and carbide 0.4-0.6)
3. **Temperature** – due to high speed and friction b/w metal to metal, heat is generated.

4. **Surface condition**- surface condition is also important in tube drawing if surface condition is smooth than that might pose a problem in draw as we would need a kind of porous surface on the topmost layer for smooth flow of material while drawing.
5. **Metal flow** – for the metal flow the atoms/ molecules of the same need space to flow. If the surface of the tube is porous than there is space for metal to flow.

2. Introduction Pilger process- Pilger process is a very effective metal cold working process for steel tubes, and other materials. It is basically a mix of extrusion and rolling together. With this process, reduction up to 95% is possible. Whenever very high reduction in thickness is required, this is the preferable way of doing this rather than cold draw. At the same time, this is a very slow process, with the best of pilger mills giving an output of 300 Kg per shift.





Pilger process Die and mandrel used in the pilger process

2.1 Factors affecting pilger process:

1. **Speed and time** –the speed of pilger process is significantly small.
2. **Friction** –friction b/w metal to metal contact without surface treatment (steel and carbide 0.4-0.6)
3. **Temperature** – due to friction b/w metal to metal, and due to cold working, heat is generated, as a result temperature increases.
4. **Surface condition**- surface condition is also important in tube drawing if surface condition is smooth than there is more problem in tube draw.
5. **Metal flow** – for the metal flow the metal particle need space to flow. If the surface of the tube is porous than there is space for metal flow.

3. Difference between tube drawing process and pilger process

1. Speed – speed of the pilger process is significantly lesser as compared to tube drawing process which results in lesser generation of heat. Hence, there is lower temperature
2. Friction – In the tube drawing process friction is high than pilgering process. Reason being that a compact air tight die is being used to draw the tubes in drawing process; while pilgering is more like rolling. The contact area is significantly smaller in case of pilger process.
3. Temperature- in the pilgering process the speed is low than draw process so the temperature is low .because there is time more metal flow
4. Surface condition – Same in both the cases.

5. Metal flow- in the pilger process metal flow is easier than tube drawing, because:

   i. Contact area is very smaller in pilger process as compared to the drawing process.
   ii. Speed is lower, significantly lower in case of pilger process, and there is a back and fro as well as rotating motion to cause the metal to flow.
   iii. The reduction in one step is smaller, hence smaller amount of metal needs to flow, which is easier than in case of cold draw.

The pilger process, thus, seems to be less rigorous in terms of speed, temperature, and other such factors; which make it possible to do with lubrication like TDN 81.

4. Lubrication in Metal Drawing /surface treatment-Lubrication is an important factor when manufacturing by metal drawing, its application can help control the forces and metal flow. Lubrication will also extend the life of the mold, reduce temperature and improve surface finish. Different soaps and oils may be used as lubricants. With difficult to draw metals, polymers or soft materials may also be used as lubricants. There are two basic methods of applying lubrication often employed in metal drawing manufacture.

5. Effects of surface treatment –Their enhanced performance features allow for increased tool and die life, cleanliness in the operation, excellent corrosion protection, and low moisture absorption. Other benefits include:

- Minimization of metal surface damage, thus fewer rejects
- Reduction of heat generated, preventing residue build-up, keeping dies cool, and extending tool and die life
- Ease of cleaning
- Higher drawing speeds
- Better surface quality
- Upper layer works like permeable membrane (porous surface)
- Reduce friction
- Reduce temperature
- Make surface condition draw able
- Make space and time for metal flow

6. Surface treatment process - Phosphate coating for drawing of tubing are now formed with weights of 4-10 g/m². This has improved the efficiency of the surface treatment and, at the same time, avoided the adverse effects which act in the first drawing stage where coarser-crystalline phosphate coating are found. The most suitable coating is based on nitrate/nitrite accelerated zinc phosphate, formed at 40-75°C. At the upper end of this temperature range, the option exists to use self-dosing nitrate type systems. Chlorate accelerated zinc phosphate baths are also found. In all cases, the preferred form of the phosphate for cold drawing of tube and section is strongly adherent but soft structured. In the drawing of welded tubing, the seam must first be ground down. In the case of smaller diameter tubing, this is not possible inside the welding machine. In some cases, there may be a deformation to give a particular cross-section. Since, as a rule, less severe deformations can be tolerated by welded, as opposed to seamless tubing, the use of phosphating is widespread, coating weights being of the order 1.5 - 5 g/m². These are mostly based on zinc phosphate baths operated between 50 and 75 °C with additives used to promote thinner coatings.Phosphating is also used for tubing of un-alloyed or low-alloyed steel with chromium content up to 4-6%. Such coatings offer a number of advantages, all arising from reduced metal-to-metal contact between tubes and die.

Thus, cold welding damage, leading to grooving or crack formation, is minimized, tool and die life is extended and higher drawing rates may be used. Zinc phosphate coating also allows a greater degree of reduction per pass.

Surface treatment is carried out by immersion along the following lines:

- Alkaline degreasing.
- Water rinse.
- Pickling in sulphuric or hydrochloric acid.
- Water rinse.
- Neutralising pre-rinse.
- Phosphating.
- Water rinse
- Neutralising rinse.
- Lubrication.
- Drying and storage.

In earlier times, the surface treatment of tubes used to take place using bundled tubes lifted by a manually-operated hoist from one tank to the next. More recently, automatic conveyors have been introduced and, while retaining the sequence of operations listed above, the whole operation takes place automatically.

Zinc phosphate contain acidic elements phosphoric acid (H_3PO_4) which make the tube surface porous

Steel before surface treatment **Steel after surface treatment**

The porous surface (small surface holes) absorb lubricant (oil/soap) like sponge. The Zinc Phosphate enters into the holes and forms a lyer on the tube surface. .

Coefficient of friction between carbide and steel is 0.4-0.6, very high to allow any relative movement for cold working.

The coefficient of friction after lubricating/surface treatment is 0.13 and 0.14 which is significantly smaller than the carbide to metal friction coefficient.

Comparison between used lubricants - Surface treatment, in fact, increases the Rz value of the tube surface. We have taken some sample observations of the tubes after surface treatment.

We took tube samples of the same material and from same lot (Same lot means tubes produced in the mill in one go from same material) and performed surface treatment with different chemicals, which are

- Zinc phosphate
- Oil B
- Oil D

The result of the test is that the Rz value for the phosphate treatment is max. And the Rz value for the Oil B is minimum (Low Rz means less perforated tube surface)

Chemicals	**Rz value**
Zinc Phosphate	5.73-6.43
Oil D	5.63-5.69
Oil B	2.70-2.74

Rz - average maximum height of the profile (vertical)

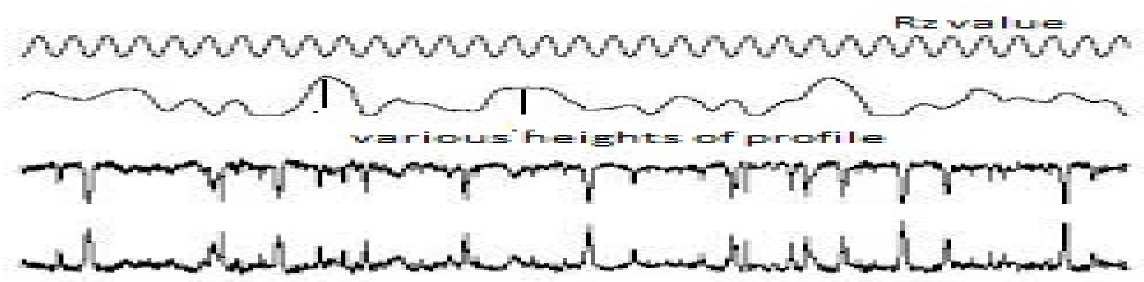
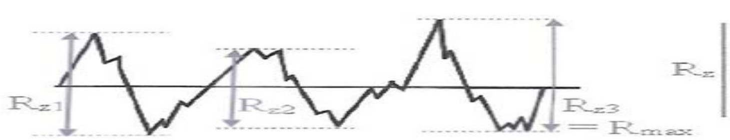


Fig. Rz value

The Mean Roughness Depth (Rz) - Rz is the arithmetic mean value of the single roughness depths of consecutive sampling lengths



Rz = (Rp +Rp) within the sampling length.

Rp - The roughness peak is the maximum height of the profile above the mean line within the sampling length.

8. Trials with oils which failed in draw process –

8.1 Oil (A) – It is a highly viscous polymer enhanced lubricant containing high levels of lubricity additives, chlorinated EP additives and a newly developed phosphorous technology addition. It is suitable for the most extreme operations. We dipped the tubes into the oil for twenty minutes, and subsequently put it into the draw process. We found that in each case, there were significant metallic lines, sometimes deep into the tubes. Galling could also be observed. The photograph of the same can be found below:

8.2 Oil (B) – It is highly chlorinated extreme pressure oil blended with fatty additives which give it unique drawing properties for the most severe Conditions (used in pilgering). We conducted trial with this oil. Similar process was used, the tubes were allowed to soak the oil for half an hour. However, the results were unsatisfactory. In fact, when the tubes were subjected to cold draw, it distorted the tubes, and subsequently caused breakage in the same. Photograph of the same is below:

8.3 Oil (C) – Oil "C" exhibits outstanding levels of mechanical and thermal stability making it particularly suitable for use in the wheel bearing of passenger cars, buses, farm equipment, off highway and non highway commercial vehicles include new generation Multi-Axle trucks for long service. The results with Oil "C" were the same as with the Oil "B".

8.4 Oil (D) – This oil is currently used here in "Caparo Engineering India Ltd.". We are currently using this oil as per the process mentioned earlier in this study. The surface of the tube after draw is like mirror.

9. Comparison sheet for Oil Draw

Name/	Density at	Kinematic	Flash	Additives	Inorganic	Appearance	Pour	Used mainly

Spec	**20 °C**	**Viscosity at 40 °C**	**point (°C)**		**acidity**		**point**	**for**
Oil (A)	1.20	4000 **cSt**	170 Degree Celsius	Chlorinated EP additives, newly developed phosphorous technology addition	Not given	Clear Amber liquid	-9 °C	**Mostly suited for cold drawing deep drawing** Stainless Steel and Nickel tubes
Oil (B)	1.15	130 **cSt**	150	Chlorines, Vegetable fats, Sulphur	Nil	Clear brown amber fluid	N/A	Cold pilgering for Stainless steel tubes
Oil(C)	0.89-0.92	135-165 **cSt**	More than 285 degree	Mineral oil (58.5%)	N/A	Yellow brown, transparent fluid	N/A	Aluminum wire
Oil (D)	0.935	40.00 **cSt**	More than 150 degree Celsius	-	Acidic	Brown liquid	-	Cold Draw

10. Conclusion- The aforesaid discussions, experiments conducted and analysis all point to the very complex nature of cold draw process. The surface treatment works at a microscopic level to change the appearance and surface of the steel. The surface required for any cold draw is very unique, and the processes in surface treatment make it possible to achieve such kind of surface, which is porous at the top. This porous surface keeps the lubricants and reproduce it when subjected to cold draw; it makes films as soon as old films are destroyed, all that at high rate, which is a pre-requisite for the process.

The comparative analysis and the trials have shown that such kind of surface is not formed when we are using oil which is not reactive in nature and which has not created a porous surface. It cannot create films which are enduring. The high speed of draw, the large contact area as well as the heavy reduction in just one go makes it a severe process as far as the surface condition is concerned. That the porous surface keeps on creating films and keeps on reproducing the lubricants while subjected to cold draw is sine qua non for the process.

11. Acknowledgment - I am very pleased to express my deep sense of gratitude to my esteem guide **"Mr. Abhishek Bharti",** Head **–** Engineering, Caparo Engineering India Limited, Tube Div. (India) for his valuable guidance, encouragement and facilities provided during the Project Work.

There were umpteen moments when I learned heavily from him. It is the fact, without his construction and simulating criticism arduous but invaluable advice sought time to time, masterly guidance deep personal interest and attention, this work would not have seen the down of the day and could never have attend the present stage.

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