

## Criterion determination of completely worn out elements of tribomechanical system on cable industry extruders

Dipl.-Ing. **Canic Z.**, DD Energetski Kablovi, Jagodina  
Dipl.-Ing. **Mitrovic S.**, MultiComp, Kragujevac, Yugoslavia

### ABSTRACT

The effect of wear between screw and barrel, as a tribomechanical parameter, on extrusion of thermoplastics materials has been presented in this work.

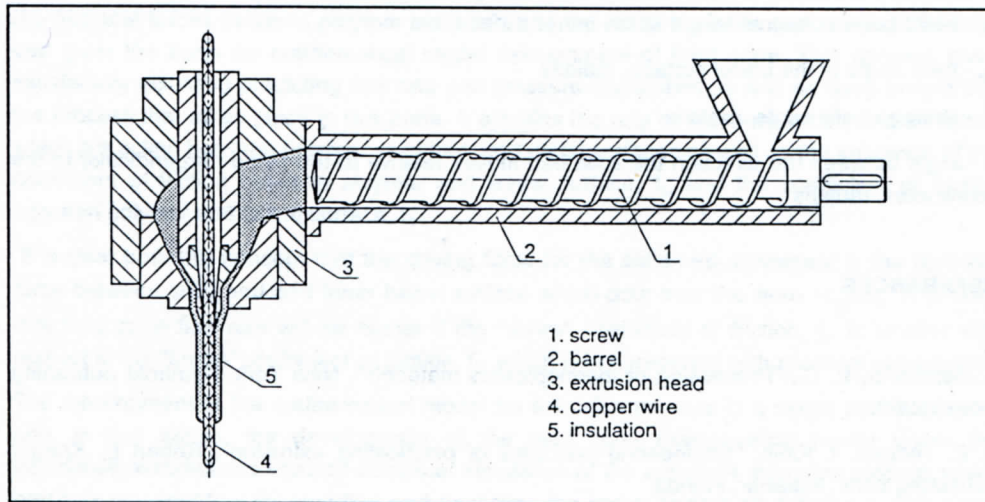
Growth of a radial clearance between barrel and screw as a consequence of surface wear, could be controlled during extruder operation which can be valuable for cable production since both, the extruder output rate and extrudate quality, are in direct proportion with the value of the radial clearance.

Criterion determination of completely worn out extruder elements in a cable industry, (screw and barrel), enables on time preventive intervention in the sense of reparation and production new elements (screw and barrel) which would greatly reduce the cost of production.

**KEYWORDS:** extrusion, screw, barrel, polymer

### 1. INTRODUCTION

Extrusion process is normally applied for insulation of wires and cables in a cable production. This process is used not only for insulating but for sheeting of semi-finished cables, too. It involves transformation of a solid polymer, usually in the forms of granules, into void free homogeneous melt as the most convenient form for application for wire and cable production and machine which does this job is called extruder. The basic trybo-mechanical system (TMS) of each extruder are barrel, screw and extrusion head which is shown in figure 1.



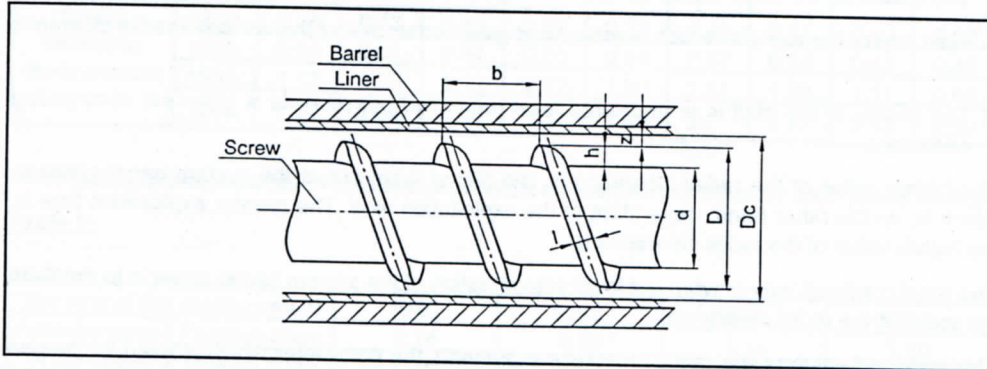
**Figure 1:** Basic elements of extruder TMS-a, 1-screw, 2-barrel, 3-extrusion head

During the extruder exploitation, the wearing process starts to develop so this process can stop the production on corresponding extrusion line. In order to be able to prevent the line stoppage as well as keeping the quality of molten polymer at desire level for application, it is necessary to work at the investigation of the process of the wear development, to determine the form of the wear as well as to determine the criterion of fully worn outs elements of TMS-a.

## 2. BASIC FUNCTIONS OF EXTRUDER TMS ELEMENTS

Extrusion head forms the insulating layer of desired thickness (insulation and sheet) of corresponding polymer (PVC or other suitable polymers for this purposes).

Typical trybo-mechanical system barrel-screw is presented in figure 2.

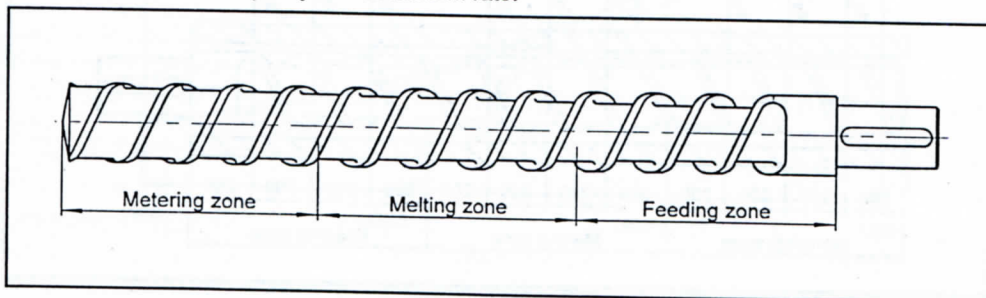


**Figure 2:** A trybo-mechanical system barrel-screw

In this TMS which is shown in figure 2, solid polymer is conveyed, melted and pumped through extrusion head as a melt of desired quality and at uniform rate. It is obvious that many processes take place in this TMS (solid polymer conveying, melting, mixing and pumping) which are dependent, of course, on screw geometry besides operating conditions and physical and chemical characteristics of the polymer being extruded.

Taking into consideration above stated, an extruder screw is usually divided into three functional zones (see figure 3):

- feed zone in which solid polymer usually in the form of granules is conveyed,
- melting zone (compression zone) in which melting process of the polymer takes place and
- metering zone in which polymer, under assumption, is fully melted and is mixed and pumped as a melt of desired quality and at uniform rate.



**Figure 3:** Functional zones of a screw

### 3. WORN OUT PARAMETERS OF SYSTEM BARREL-SCREW AND THEIR EFFECT ON EXTRUDATE QUALITY

Some of the analyzed extrusion lines in the cable industry has been supplied in the period of 1970 to 1980 show very serious extruder flow rate drop. The geometry of the was changed as well as the radial clearance between the top of the screw flight and barrel which cause reduction of the melting rate of given polymer which lead to undesired extrudate quality (cold spots, unmelted polymer in the extrudate).

In order to establish the level of wear between barrel and screw it is necessary to control several characteristic parameters:

- The clearance between the screw and barrel.
- Flow rate of the extruder which is reduced at given screw speed thanks to the radial clearance rise.
- The quality of the melt is at undesired level (unmelted polymer) for a given set of operating conditions.

The higher value of the radial clearance is, the higher worn out of the system barrel-screw is, which is, on the other hand, dependent of the exploitation time. The greater exploitation time is, the higher value of the radial clearance is.

The most confident way of worn out level determination of the system barrel-screw is to measure the value of the radial clearance.

This obtained value of the radial clearance represents the parameter which is used for precise prediction of the extruder performance behavior during production, the parameter which can be used for redefining the operating conditions of given extruder as well as it gives possibility to decide whether to repair given extruder or to change given extruder with new one or not.

### 4. THE DEVELOPMENT OF WEARING PROCESS OF THE SYSTEM BARREL-SCREW CONTROLLED BY THE RADIAL CLEARANCE MEASUREMENT

In order to determine the degree of the wear between barrel and screw, it is necessary to measure the radial clearance periodically, during the exploitation of the extruder. With this purpose, corresponding measurements of the radial clearance for given extruder was made in the period from 1980 to 1995 with time gap of 5 years between each measurement. For this radial clearance measurement it was chosen 9 measuring points with the distance between them of 200 mm which is shown on figure 4.

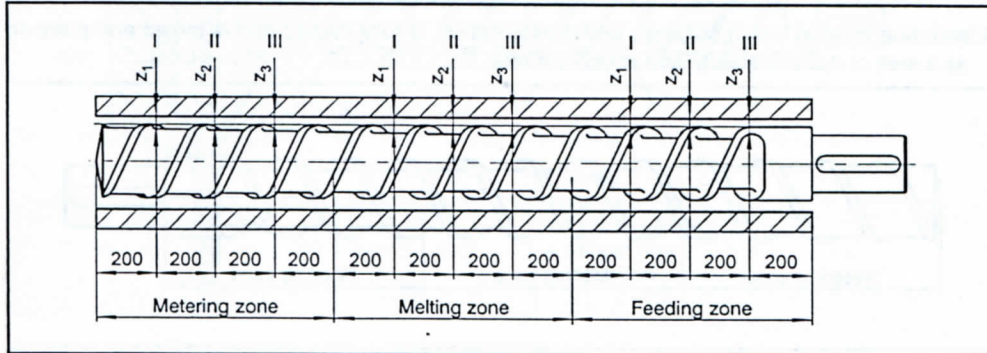


Figure 4: The location of the measuring points on the screw

Measurements were made in the production conditions on the steam CCV line which is used for wire and cable insulation process using cross-linked polyethylene (XLP) being processed on 41/2" extruder. Measurements of the screw diameter were done by an instrument whose precision is 1/100, while inside barrel diameter measurements were made using special instrument which is normally used for cylindrical hole measurement.

The radial clearance measurements for given extruder are presented in table 1.

**Table 1:**

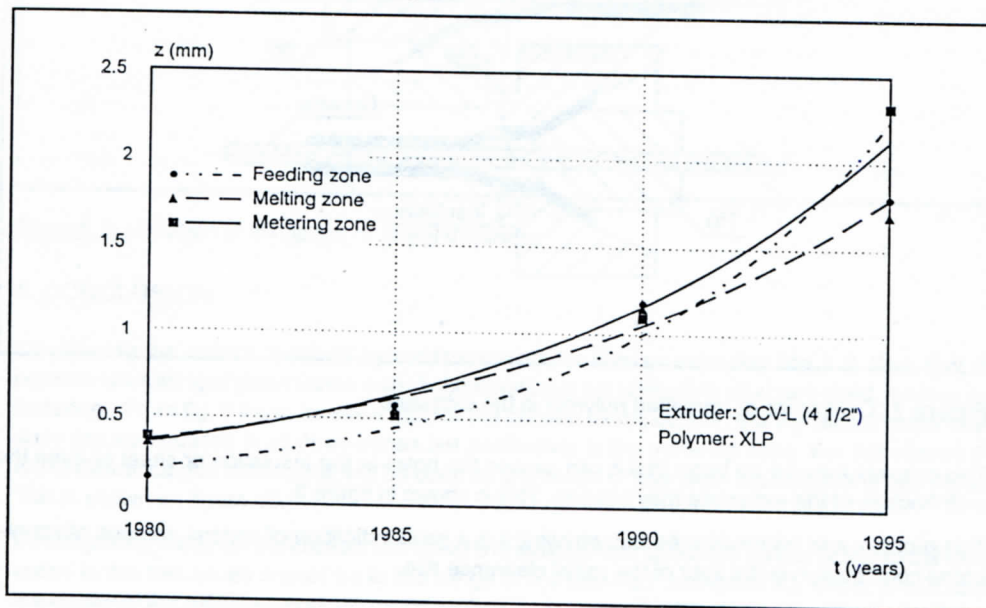
Zones		Feeding			Melting			Metering		
Location of measurement		I	II	III	I	II	III	I	II	III
Radial clearance measurement (mm)	1980.	0.15	0.13	0.15	0.27	0.38	0.43	0.51	0.40	0.26
	1985.	0.58	0.61	0.54	0.56	0.59	0.57	0.55	0.55	0.45
	1990.	1.17	1.25	1.12	1.12	1.20	1.22	1.08	1.11	0.89
	1995.	1.72	1.81	1.89	1.37	1.69	2.01	2.15	2.43	2.39

In the table 2 average values of the measured radial clearances are given for each screw section.

**Table 2:**

The year of the measurement		1980.	1985.	1990.	1995.
Average value of the radial clearance	Feeding zone	0.14	0.58	1.18	1.80
	Melting zone	0.36	0.57	1.18	1.69
	Metering zone	0.39	0.52	1.03	2.32

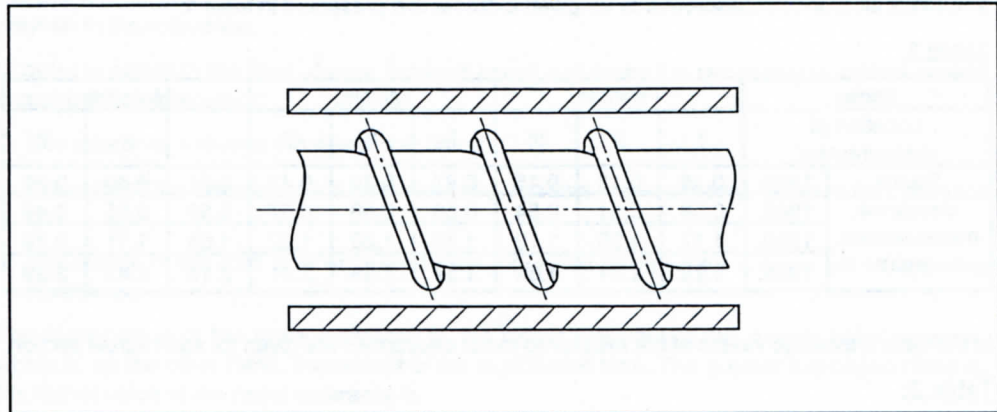
On the bases of the results presented in table 2, corresponding "wear curve" are made for each zone respectively, which is shown on figure 5.



**Figure 5:** Wear process development in production conditions for given barrel and screw combination

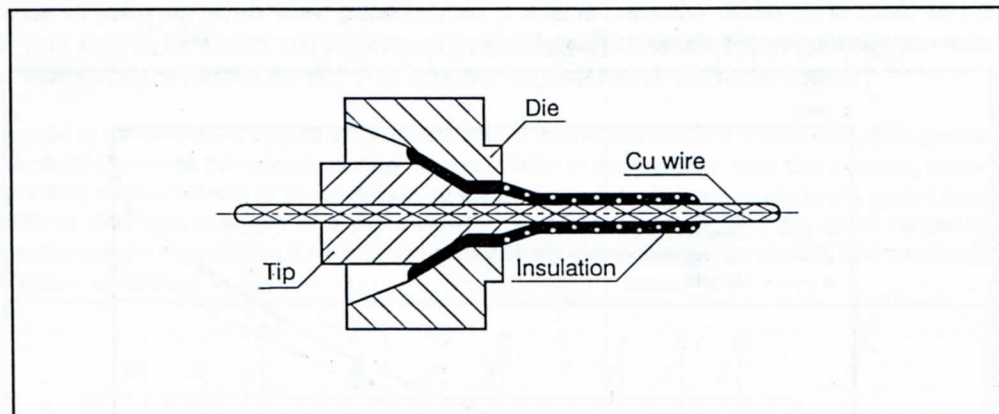
From the above results, it is clear that radial clearances for given screw-barrel combination were raised which represents undesired conditions in wire and cable production.

In the feeding zone of the screw, the tops of the flight are oblique and there is a sliding of the solid polymer going back which causes the insufficient feeding of the two next zone leaving them without enough polymer. This case is shown on figure 6.



**Figure 6:** The oblique ends of the tops of the screw flight

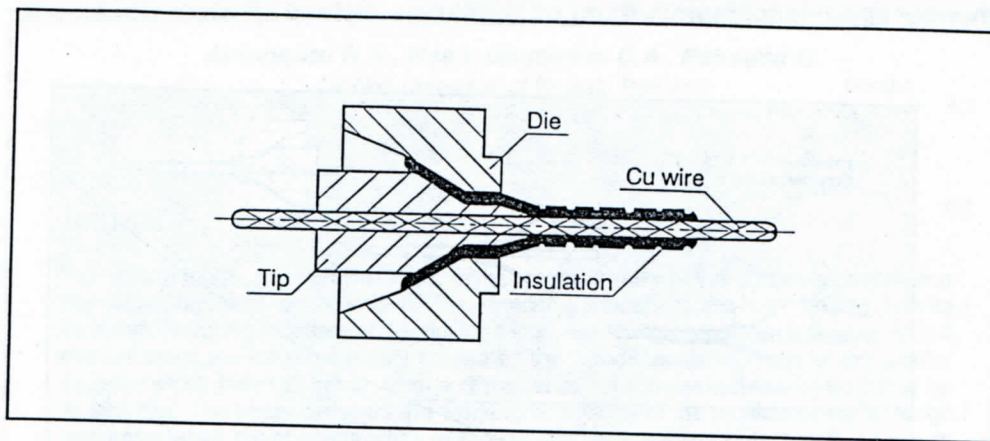
As the consequence of this above stated, melting rate of the polymer for given operating conditions are reduced and cold spots or unmelted polymer appear in the extrudate which deteriorate the quality of the extrudate, which can be seen on figure 7.



**Figure 7:** Cold spots or unmelted polymer in the extrudate

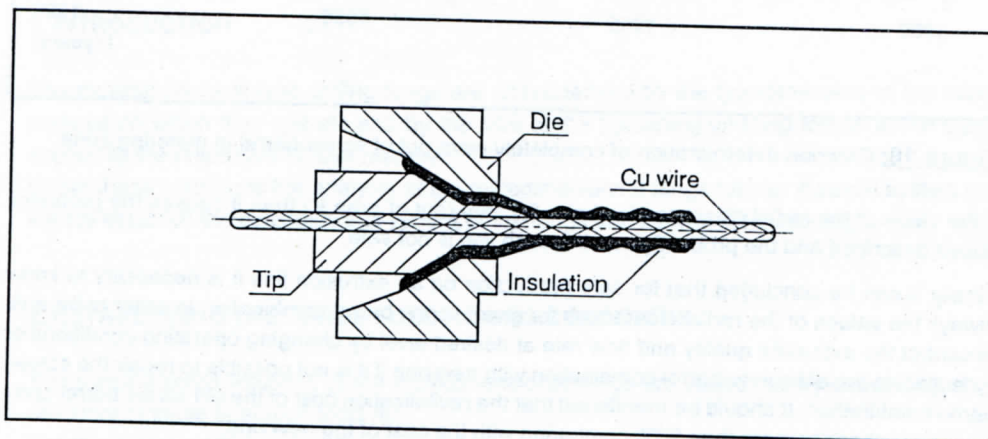
This process may be so large that it can causes the holes in the insulation or sheet or even the melt fracture of the extrudate may happen. This is shown in figure 8.

This problem can be moderated but, anyway, it is a good indication of serious damage of screw-barrel combination in the light of the radial clearance rise.



**Figure 8:** Melt fracture on insulation or sheet

Temperature fluctuation of the extrudate changes the viscosity of the melt, which, in turn, change the pressure and flow rate which causes the variation of the thickness of insulation or sheet and it may appear as a "waves" on insulation or sheet. This is shown on figure 9.

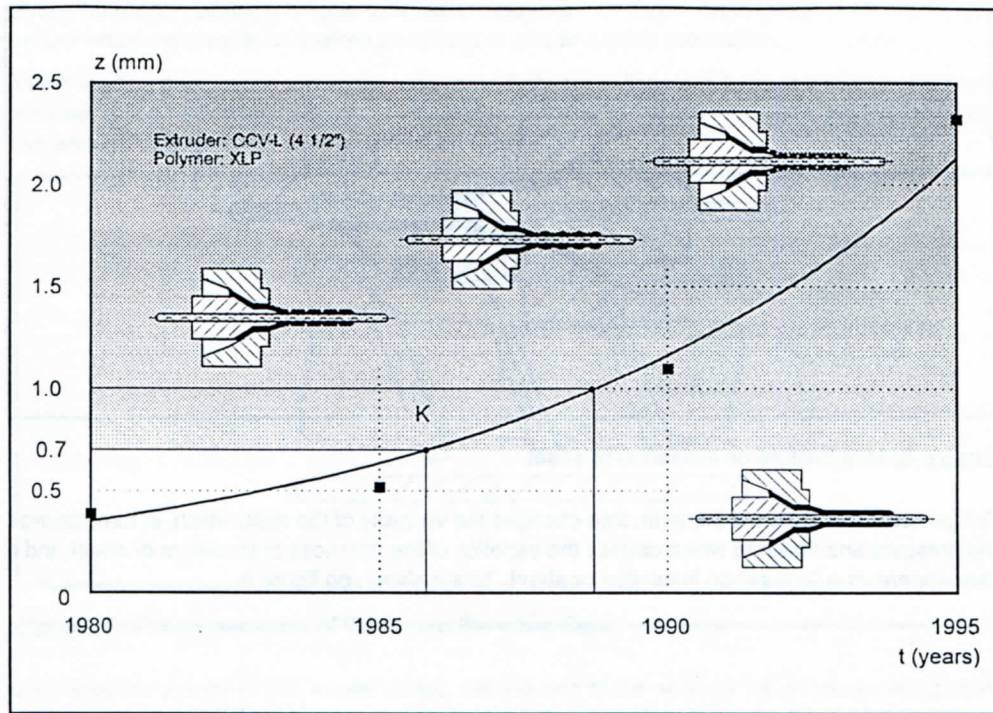


**Figure 9:** Variation of insulation or sheet thickness

## 5. CONCLUSION

Considering the results obtained by measurements for chosen extrusion line it is clear that the process of wearing of given screw-barrel combination is not uniform in all zones (feed, melting and metering). From fig. 5 it can be seen that for the chosen extrusion line, the significant radial clearance rise was noticed in all three zones but particularly in the metering zone. For this reason the radial clearance rise in this zone will be used as a criterion of fully worn out element of this TMS-a. This is shown on figure 10.

Investigations made on the chosen extrusion line indicate that allowable values of the radial clearances in this two zones should be in the range of 0,4 mm - 0,7 mm (area K), since, in this case, the quality of the extrudate can still be controlled by adjustment of operating conditions (the clearance between tip and die, screw speed variation, temperature setting modifications).



**Figure 10:** Criterion determination of completely worn out of screw-barrel in metering zone

If the value of the radial clearance is above 0,7 mm (out of area K) than it causes the problems above described and the production on the such line is not safe.

Finally, it can be concluded that for safe production on an extrusion line it is necessary to know always the values of the radial clearances for given screw-barrel combination in order to be able to control the extrudate quality and flow rate at desired level by changing operating conditions or by replacing the old screw-barrel combination with new one if it is not possible to repair the screw-barrel combination. It should be mentioned that the revitalization cost of the old screw-barrel combination is cheaper more than 50% comparing with the cost of the new one.

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