УДК 621.923

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INFLUENCE OF TOOL AND TUBE OVERLAP ON AXIAL LOAD CAPACITY OF TUBE AND FINNED SOCKET ASSEMBLY IN FLUE GASSES ECONOMIZER

This project presents results of experimental research of tube and finned socket assembly axial load capacity in flue gasses economizer. Pressed overlap was created by tube widening with tool passing through the tube. Goal of the research was to define a diameter of the tool for tube widening, which will, with minimal overlap, provide linear load capacity of pressed assembly, which has to be higher then working force, already at 220mm of the assembly length.

Features of economizer tubes. Economizer tube is assembly steam boiler tube and finned sockets which are threaded on the tube. Steel steam boiler tube provides air tightness and finned sockets made of cast iron provide large surface for heat transmission, and they are resistant to sulfur acids which are present in flue gasses in thermo power plants which use coal with higher sulphur content. Good connection and low heat transmission resistance between tubes and finned sockets is enabled by pressed overlap. Assembly is shown on figure 1. Length of the assembly can be as long as 10 meters, and length of finned socket is 300mm, so total number of sockets can be as high as 30 pieces.

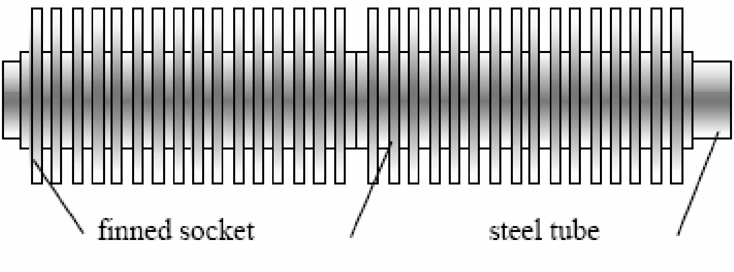

Figure. 1. EKO tube assembly

To provide pressed overlap between the tube and the socket, widening tool is being passing through the tube . Tool is presented on figure 2.

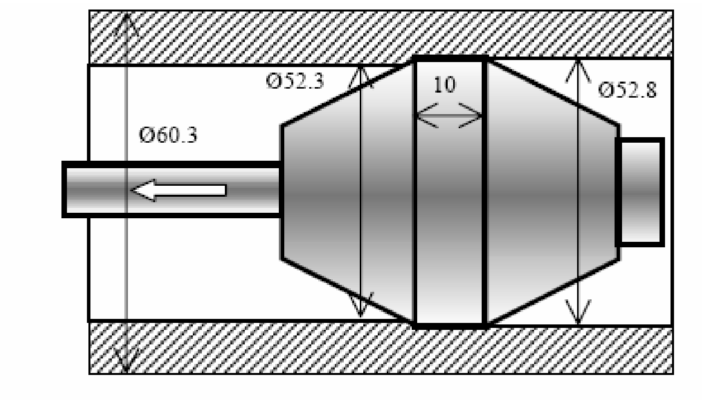

Figure. 2. Tube widening tool

Basic idea is to lean axially tube and a socket in the beginning of widening process. During the widening process, material flow occurs in direction of tool motion therefore it is necessary to release the tube in axial direction after 220mm of tool working stroke, after which tube is supported only by finned sockets. Working force of tool will move a tube and the pressed overlap will pack all sockets one to another. That way is performed tightness which will prevent sulfur acids to get to the surface of the steel tube. If axial load capacity at 220mm of length is equal or higher then working force necessarily for tube deformation and creation of pressed overlap, process of deformation is being continued. If axial load capacity is smaller then working force, tube slipping occurs. In that case, deformation process is being terminated , and widening tool is being replaced with one which has larger diameter.

Device for assembly testing. In available literature there is no suitable analytic model which would define tool diameter for this process. The most similar is the process of plastic deformation when tube ends are being narrowed., process of extruding. This analytic model is developed with assumption that walls of the extrusion tool are absolutely stiff, which is not a case with finned socket which material is suffers elastic deformation. Therefore in this case, such model can be used only approximately as a method to define forces in the start of the process, by which tool's and construction elements' dimensions and materials are defined to perform experimental research. By tool and tube dimensions shown on figure 2, and equations for deformation force:

$$F_d = A_0 \cdot k_m \cdot \ln\frac{A_0}{A_1} \cdot \left(1 + \frac{1}{2} \cdot \frac{\alpha}{\ln\frac{A_0}{A_1}}\right)$$

and friction force [1]:

$$F_{tr} = \mu \cdot \left(2 \cdot \frac{A_0 \cdot k_m \ln\frac{A_0}{A_1}}{\alpha} + \pi \cdot D_0 \cdot h_0 \cdot k_m\right)$$

A_0 – ending deformation surface; A_1 – starting deformation surface; μ – friction coefficient; D_0 – diameter at the end of deformation process; h – length of contact between tube and tool; α – angle of tool cone km- specific deformation resistance of the tube.

Approximate total value of working force which is required for creation of pressed overlap is:

$$F_{working} = F_d + F_{tr} = 67kN$$

Based on this load value, testing device and tool were constructed which will be used for analyze of pressed overlap features on standard tensometric device for material testing (figure 3).

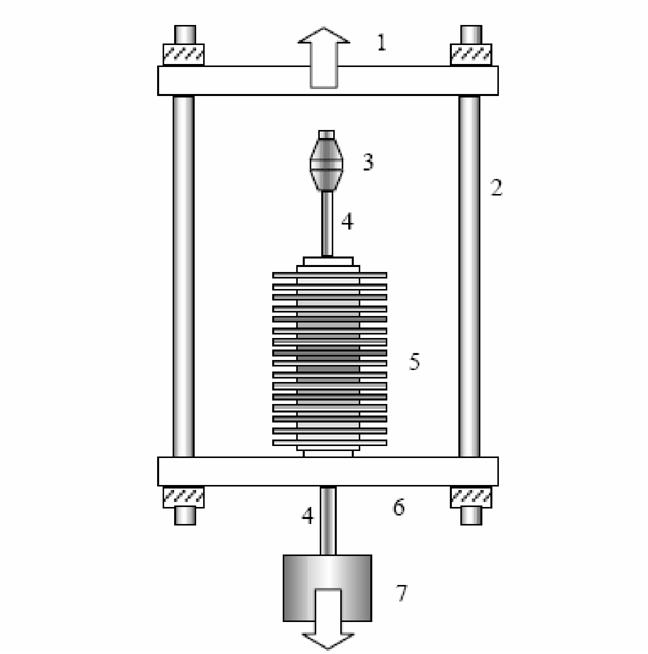

Figure 3. Testing device

Positions on figure 3 are:
1 – testing device traverse;
2 – support pillars;
3 – widening tool;
4 – pulling rod of the tool;
5 – EKO tube assembly;
6 – lower traverse;
7 – lower clamp of the device.

Support pillars (2) are placed through the holes in traverse (1). Traverse of testing device (6) is connected with hanging pillars. In the middle of this traverse is placed a hole through which is placed pulling rod (4) of widening tool (3). EKO tube assembly (5) leans on the hole edge. Pulling rod is connected with its' lower end into clamp of the testing device (7). A fastening bolt of toll is placed into its' upper end. By starting the testing device, upper traverse lifts and pulls lower traverse together with leaned EKO tube assembly. Pulling rod remains rigidly connected to lower clamp of the testing device EKO assembly goes to the widening tool, which starts creation of pressed overlap. On figure 4 is presented the way that tube and finned socket of EKO assembly leans on the lower traverse

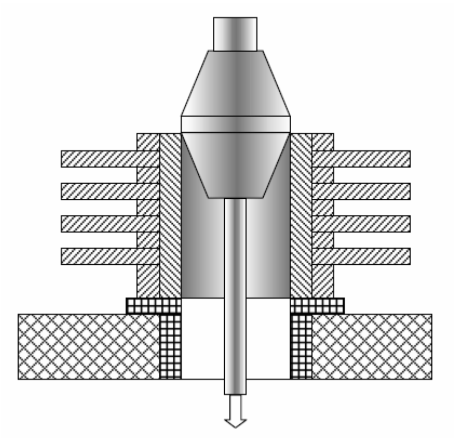

Figure 4. Leaning of EKO assembly on lower traverse in the pressed overlap forming phase

After tool gets through the whole EKO assembly, tool is being removed, traverse goes down, and support tile under EKO tube assembly is being removed, so now assembly leans only over a finned socket surface. Instead of the tool, pressing board is placed which has such 1 2 3 4 5 6 7 4 dimensions that it can get into internal hole of finned socket. When device is being started again, board press the tube with goal to squeeze out the tube and to demolish pressed overlap. The way tube and finned socket of EKO assembly leans on lower traverse in this phase is shown on figure 5.

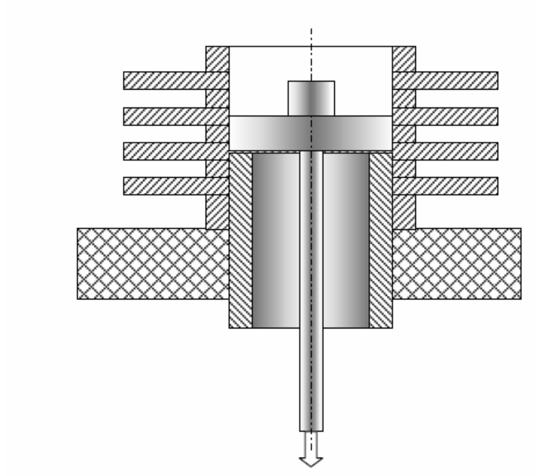

Figure 5. Leaning of EKO assembly on lower traverse in the pressed overlap demolishing phase

Results of experimental research. Experimental measurements of work force and axial load capacity of pressed overlap was performed on assemblies which were made by set of tools with different dimensions. A goal was to define such tool dimension which will provide axial load capacity of pressed overlap, with 220mm in length, to be higher then work force used for creation of assembly. At the same time, working force and created overlap should have as less as possible values due to increase of fabrication speed and small parts of the machine used for creation of pressed overlap. To reduce part of working force caused by friction, internal tube surface was lubricated with oil before tool started passing through. Standard steam boiler steel tube has dimensions O60.3.4mm with diameter tolerance ±0.6mm and wall thickness tolerance ±0.4mm. By measuring of diameters of all tubes on their ends in two orthogonal planes, average value of O52.1mm is determined. It is estimated that 0.5mm overlap of the tool and tube will be enough for creation of wanted overlap.

Based on these data, it is produced a group of tools for experimental check of following dimensions and overlaps.

a1 – O52.4, p = 0.3,

a2 – O52.5, p = 0.4,

a3 – O52.6, p = 0.5 и

a4 – O52.7. p = 0.6mm.

During test experiments, overlaps between tool and tube were gradually increased. That is why only first three tools were used further experiments. Usage of tool with maximal dimensions caused cracks in finned sockets due to high pressed overlap and stress of socket material. Tests with and without wall lubricating were performed on finned sockets with 220mm in length. Figure 6 shows value of working force for different tool dimensions and surface lubrication.

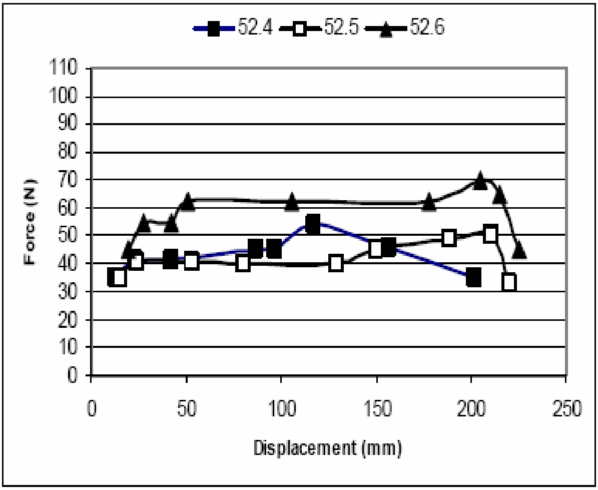

Figure 6. working forces when assembly is lubricated in length of 220 mm

Figure 6 shows that 0.3mm and 0.4mm overlaps have similar values in case of lubricated surfaces. Increase of overlap to 0.5mm provides expected change of working force. In the beginning of the process force rapidly grows. After 50mm, force achieves to its' real value of around 60kN. This value doesn't change to the assembly length of 180mm, when it raises to 70kN. This value raise is expected because tool in front of itself created a wrinkles in tube wall. Wrinkles are created because lower traverse blocked flow of the tube material in front of the tool. Figure 7 shows change of working force in case of dry and non lubricated surfaces.

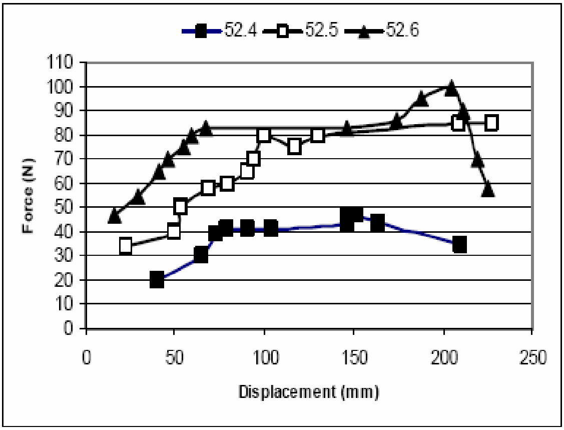

Figure 7. working forces when assembly is not lubricated in length of 220 mm

Figure 7 shows significant increase of working force for 35% due to increased friction on non lubricated surfaces. This leads to conclusion that pressed overlap of EKO tubes should be performed in with lubrication of internal tube surface. Table 1 shows value of working force for creation of pressed overlap and value of knock out force, which together represent axial stress capacity.

Table 1

length assem. [mm]	tool dimen.	working force [kN]	knock out force [kN]	assem. quality
220	Ø52.4	45	23	bad
220	Ø52.5	40	43.5	good
220	Ø52.6	62	161	cracks
2×110	Ø52.4	45	63	good
2×110	Ø52.5	50	75	good
2×110	Ø52.6	70	85	good

Table 1 length assem. [mm] tool dimen. working force [kN] knock out force [kN] assem. quality 220 O52.4 45 23 bad 220 O52.5 40 43.5 good 220 O52.6 62 161 cracks 2×110 O52.4 45 63 good 2×110 O52.5 50 75 good 2×110 O52.6 70 85 good Based on data from table 1, it can be concluded that most favorable tool is O52.5mm because with minimal working force of 40kN and 50kN provides good enough axial load capacity of EKO tube assembly. This value is recommended for single part (220mm), and double part finned socket (2×110mm). Tool with diameter O52.6mm in case of double part assembly provides good enough axial load capacity of pressed overlap, but it has increased working force for 40%. In case of fabrication of single part assembly leaded to breakdown of pulling bolt This indicates that tool with diameter O52.6mm, creates too large overlap, and demands high values of working force.

Conclusion. To make a project of machine for EKO tubes production, method is established to define working force for pressed overlap creation. Theoretical model of plastic deformation process with narrowing of tube ends, extrusion process, was used to determine value of working force and calculation of testing device elements. Experiments showed that values of real fabrication forces are under or above theoretical values, which depends on way of lubrication and tolerance of tube fabrication Each of formed assemblies which did not have visible cracks was cut in axial and transversal direction at several points with goal to check overlap of tube and socket connected surfaces. Control showed that pressed overlap was performed uniformly, which provides high quality heat transfer through contact surfaces. For each of new dimensions of EKO tube should perform testing by shown methodology in laboratory. That way it is possible to determine most acceptable tool diameter, and to check quality of created overlap.

LITERATURE:

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Подано 16.08.2007