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Hairpin bending of flat oval tubes — the solution for the recyclable all aluminium heat exchanger

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Abstract

A new method, which makes it possible to bend Flat Oval Tubes into hairpins, has been developed lately.
This new finding makes it possible to manufacture heat exchangers all in aluminium at low cost.

1 Introduction

Flat Oval Tubes have been used in automotive radiators, heater cores and now lately in air-conditioning condensers, due to the high performance and low cost compared to brazed heat exchanger solutions.

The traditional Flat Oval Tube automotive heater cores/radiators are often made from aluminium tubes and fins, which are assembled onto a water tank made of plastic and kept together by a steel or aluminium header plate.

This design is very complicated to recycle.

In today's world there is an increased demand, that products are recyclable. An all aluminium heat exchanger is an obvious solution.

Aluminium water tanks are often very costly and need, in most cases, to be brazed onto the tubing.

By using traditional Flat Oval Tubes, it has until now been necessary to have two (2) water tanks.

With this new hairpin bending technique only one (1) water tank is needed, and the all aluminium heat exchanger can be competitive also from a cost point of view.

2 The Purpose

The purpose of this new development was to ensure a heat exchanger concept, which is recyclable, has high performance and at low cost.

3 Success Criteria

To obtain an optimum design it is necessary to combine the hairpin bending of the Flat Oval Tube, with twisting the legs of the hairpin so they can be used in a staggered configuration.

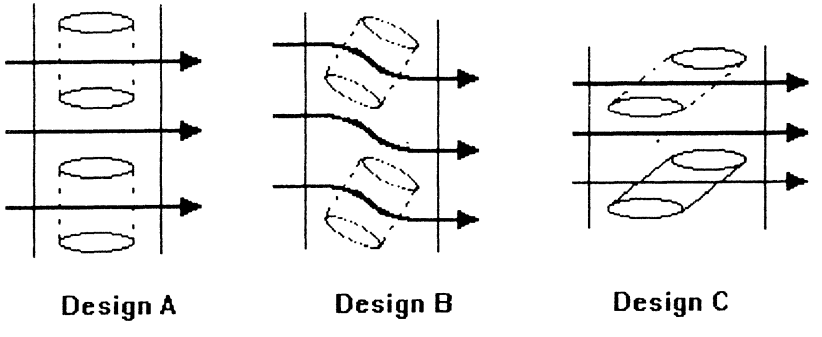


Figure 1: Design A: Complicated water tank/header design needed
Design B: Increased air-side pressure drop
Design C: Twisted hairpin legs required

Space is as important as cost of an automotive heat exchanger.

It was therefore required that the bending/twisting area of the hairpin should be as short as possible to compete with the size of a water tank.

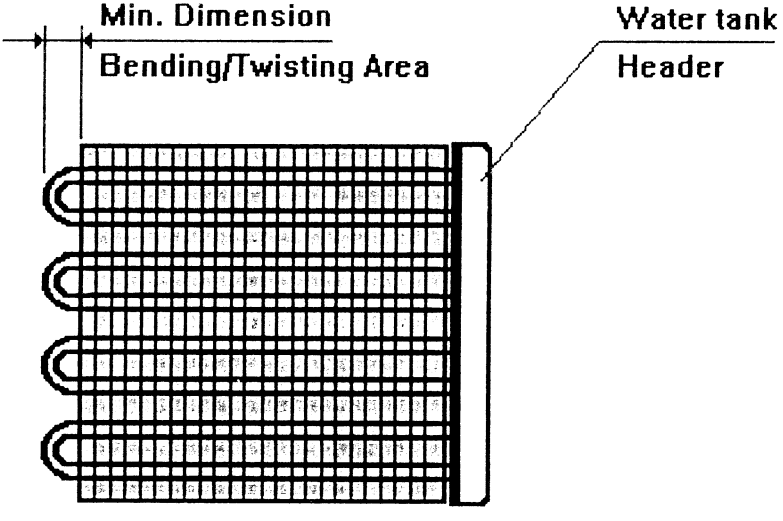


Figure 2: Typical heat exchanger showing critical bending/twisting area

4 Tube Characteristics

The Flat Oval Tubes used for automotive heat exchangers are normally in the dimension range of:

9-14 mm (major dimension)
2,5-4,0 mm (minor dimension)
0,35-0,60 mm wall thickness

The relation between minor and major dimension is 1:2,5 to 1:4,5 normally.

The most used aluminium alloy is AA3103 or AA3003.
The temper is often H111 or spot annealed (bending area) half or full hard.

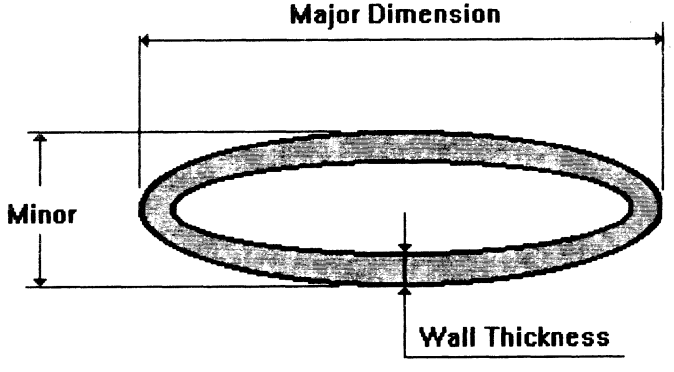


Figure 3: Typical Flat Oval Tube used in heat exchangers

5 Bending Process

The bending technique is a combination of the method with internal support known from round tubing, the described method from flat tube bending[1] which is improved further with a new technique[2].

5.1 Bending Parameters

The relation between outside diameter, wall thickness, bending radius as well as temper are the important parameters.

For bending of a Flat Oval Tube, the outside diameter is replaced by the minor dimension.

Bending radius/outside diameter ratio < 1.5 known from round aluminium tubing can be difficult to reach, due to the limited strength in the flat side of the Flat Oval Tube.
However, it is normally not necessary to bend the tube so tightly when mounted in a staggered configuration.

The quality of the bending can be described as follows:

Collapse in bending area (reduction of flow area)
Reduction of wall thickness (outside)
Build-up of wall thickness (inside)
Wrinkles inside

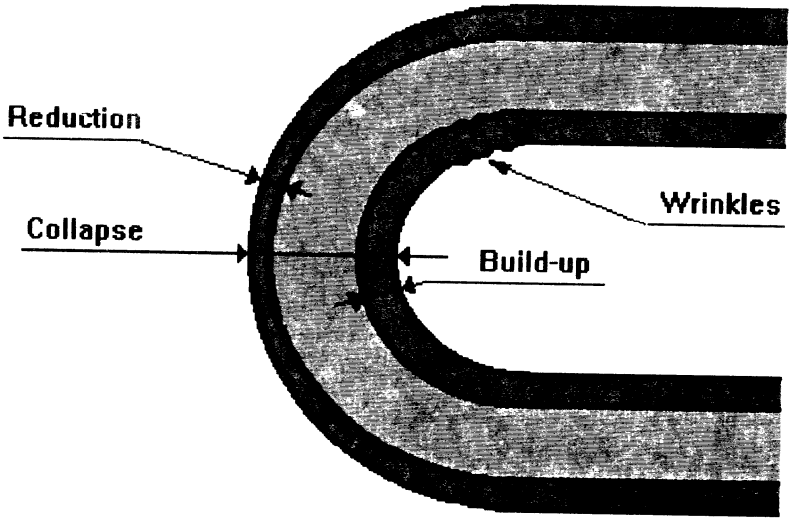
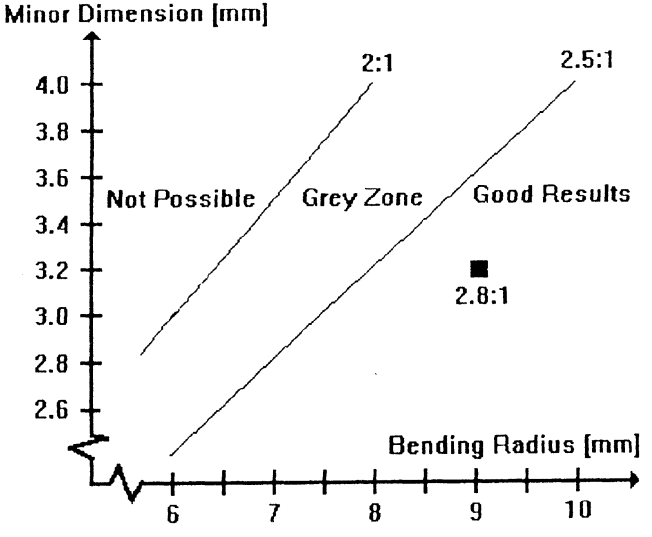


Figure 4: Cross section of Flat Oval Tube Bending

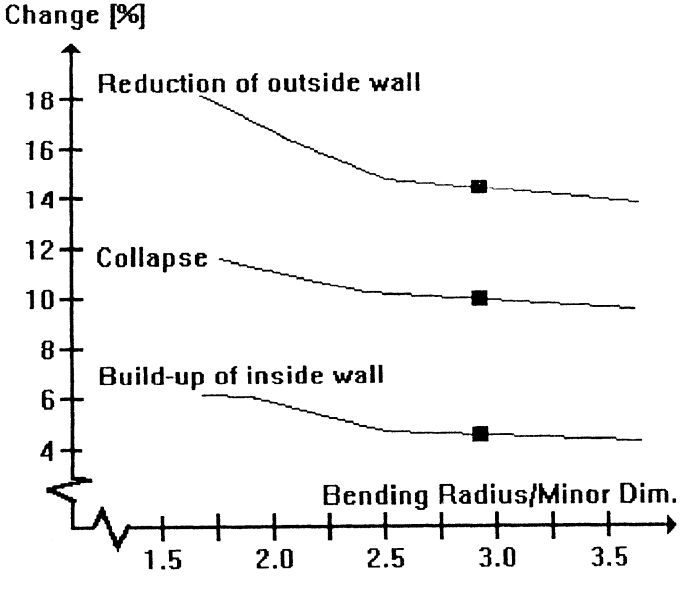
5.2 Result of Bending

The hairpin bending technique allows the material to build-up the wall thickness evenly inside of the bending, and at the same time reduce the wall thickness evenly at the outside.
Wrinkles can be avoided easily when bending process is controlled properly. However, tendency to wrinkles are expected to appear when bending radius is reduced.

The surface of the tube does not show any sign of overload/stress, which can cause the tube to fail later on.



Graph: 1: Relation between Bending Radius/Minor Dimension



Graph 2: Dimensional changes as function of bending radius/Minor Dimension.

The pressure drop through a hairpin bended Flat Oval Tube has not yet been measured.
However, the cross section of the tube is almost intact in the bending area, so no significant changes in velocity profile is expected.

The pressure drop is therefore expected to be lower than for a traditional water tank/header arrangement.

6 Twisting Process

The twisting technique is also performed with internal and external support when the Flat Oval Tube is formed.

6.1 Twisting Parameters

The relation between the major dimension of the Flat Oval Tube, wall thickness, temper and length as well as angle of twisting.

The angle of twist depends on how the Flat Oval Tubes are arranged in the heat exchanger core.
The twisting length must be as short as possible to save ineffective space.

The quality of the twisting can be described as follows:

Collapse in small radius area (reduction of flow area)
Reduction of wall thickness (in small radius area)
Graduated change of angle (no kinks/increased pressure drop)

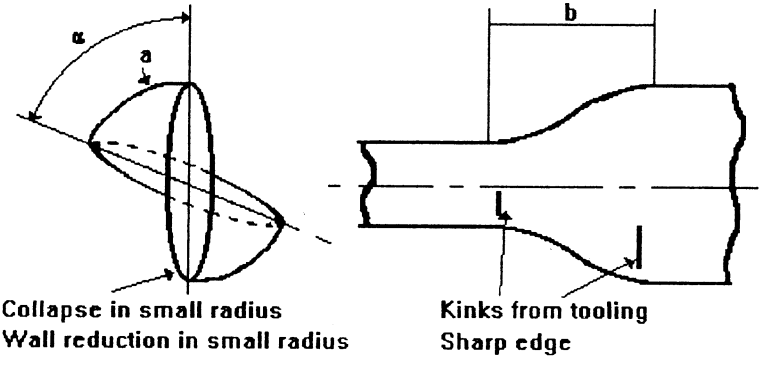
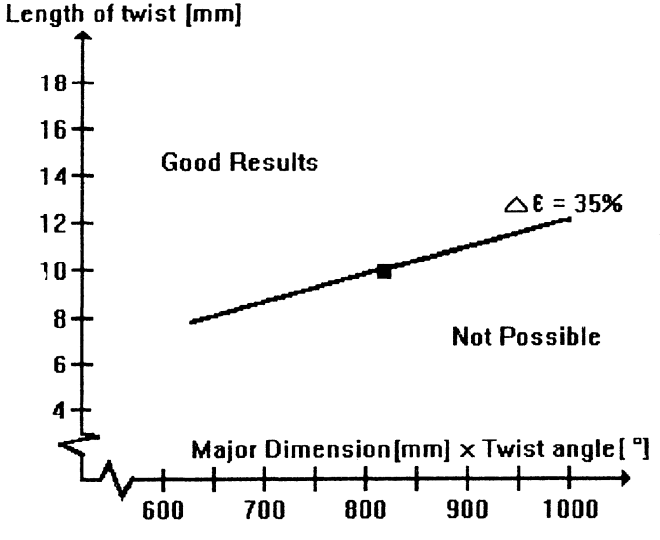


Figure 5: Side view of twisted Flat Oval Tube

6.2 Result of Twisting

The stress in the outer wall of the small radius area can be shown in a graph.

Above 35% elongation, it is likely that the tube will rupture in the small radius area, or collapse.



Graph 3: Relation between major dimension/twist angle/twist length

To avoid unnecessary pressure drop from kinks/sharp edges, it is important that the support inside as well as outside is prepared and adjusted for the specific dimension.
This is also important for avoiding collapse in the radius area.

The reduction of the wall thickness in small radius area has not been investigated yet.

7 Conclusions

The new hairpin bending and twisting technique allows us to bend a tube very homogeneously and with no wrinkles inside the bending.
The surface of the tube does not show any sign of overload/stress, which can cause the tube to fail later on.

This new technique can turn around the trend in the heat exchanger market, and especially for heater cores which can benefit from this new Flat Oval Tube hairpin bending method, but also radiators and evaporators.

The manufacturing method seems to be easy to control, and is foreseen to be suitable for mass production at a competitive level.

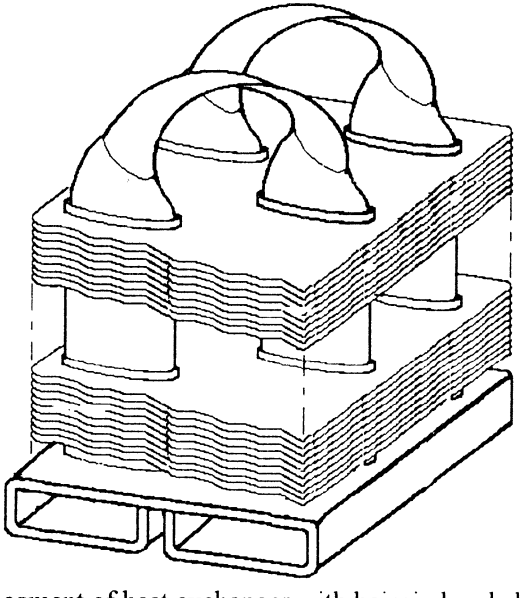


Figure 6: Segment of heat exchanger with hairpin bended/twisted Flat Oval Tubes and one (1) water tank only.

References

[1] Patent Application No. 94117924.4
[2] Patent application pending: