Innovations in ERW Mechanical Steel Tube Design with Automobile Applications

by

Junichi Tamaki / Staff Manager, Welded Tube Quality Control Sec., Wakayama Steel Works
Saburo Inoue / Assistant General Manager, Tubular Products Technolgy Dept., Tokyo Head office
Miyuki Yamamoto / Senior Research Engineer, Applied Mechanics & System Research Dept., Cooperate Research & Development Lab.
Yasuhide Fujioka / Staff Manager, Tubular Products Development Sec., Wakayama Steel Works

Synopsis

Electric resistance welded (ERW) mechanical tubes and seamless mechanical tubes are often used in applications with automobiles.

Recently, it seems a variety of features are expected and required in the automobile market. ERW and seamless mechanical steel tubes, in addition to their conventional properties, should also include innovations which reduce cost and car weight and which increase passenger safety.

This report introduces the current situation in the field of automotive accessories and, more importantly, highlights the most attractive new properties of ERW mechanical steel tubes, their high-tensile strength.

Our test facilities and tube manufacturing facilities will be fully utilized to develop and maintain the quality and competitiveness of this new product.

1. Introduction

Recently, as a result of growing environmental and economic considerations, the demand for more fuel-efficient automobiles has been increasing. New, lightweight materials are needed to replace heavier components and improve operating efficiency.

At the same time, new products must continue to satisfy the most important concern of ensuring passenger safety.

Producing components such as door reinforcements which protect vehicle passengers during side collisions, and propeller shafts, while still maintaining strength and safety standards, have been difficult to achieve using conventional materials grade. In order to meet weight and safety de mands, the high-tensile strength ERW mechanical tube has been developed.

This paper describes not only the technical characteristics of the ERW mechanical steel tube itself but also its properties as an assembled automobile component and its strict evaluation using testing equipment.

2. Applications of Mechanical Steel Tubes in Automobiles

Steel products such as sheets, tubes and bars are used in the construction of automobiles. **Table 1** is an inventory of such components.

Figure 1 shows the typical application of steel tubes in standard automobile construction.

In general the demands placed on these features call almost exclusively for electric resistance welded (ERW) tubes and seamless tubes to be used. The new and increasing demand for mechanical steel tube in

Table 1 Composition of automobile weight

Material		Weight percent (%)
Steel	Sheet	62.5
	Tube	3.0
	Bar	15.0
Non-metallic (Rubber, glass)		14.0
Others (Al)		5.5
Total		100.0 %

automobile applications has been growing for both economic and environmental reasons.

Figure 2 shows the background and demands for mechanical steel tubes.

The authors would like to share our knowledge and experiences of steel tube applications with you.

Firstly, this paper will discuss the application of steel tubes in regard to propeller shafts, and the development of side door beams as a means for increasing consumer confidence and safety.

Furthermore, the subject of using durable steel tube to meet weight and cost reduction requirements, while maintaining high strength, will be covered. Lastly, this paper will conclude with an examination of testing methods and findings.

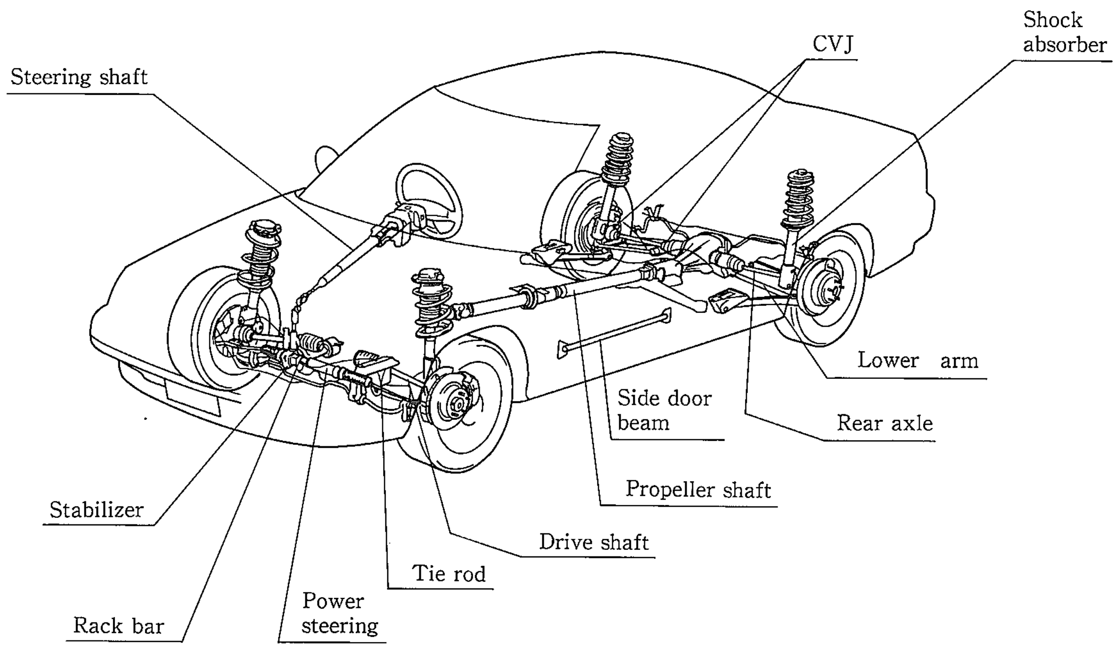


Fig. 1 Application example

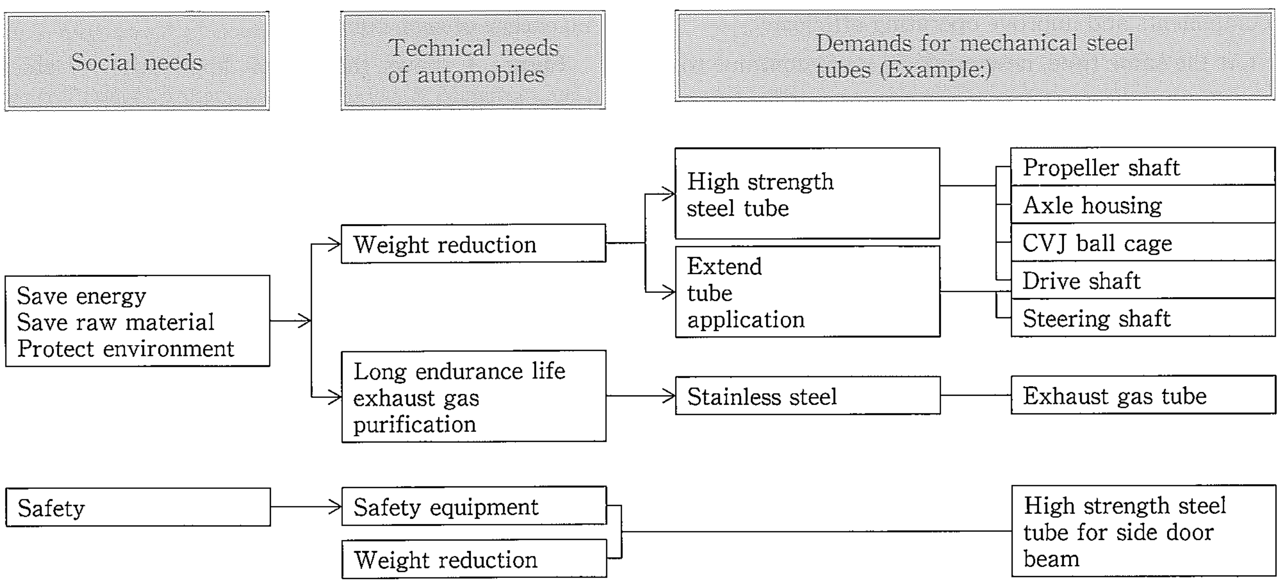


Fig. 2 Relationship between social needs and demands for mechanical steel tubes

3. Development of the High Strength ERW Steel Tube for Propeller Shafts

Driving shafts such as the propeller shaft and drive shaft are the most important parts of the automobile apparatus which transmit the engine power to the wheels. The conventional strength of the average driving shaft is around 500 N/mm² tensile strength. However, in order to achieve the desired weight reduction of automobiles, high strength ERW steel tubes have been utilized recently.

The propeller shaft (**Fig. 3**) requires performance in the following areas

① Static torsion
② Torsional fatigue
③ Dimension accuracy (Dynamic balance)
④ Weldability
⑤ Formability

Motor companies have been able to reduce the weight of their cars by 13% by applying this high tensile steel tube (For example TS 700 N/mm² grade)*1.

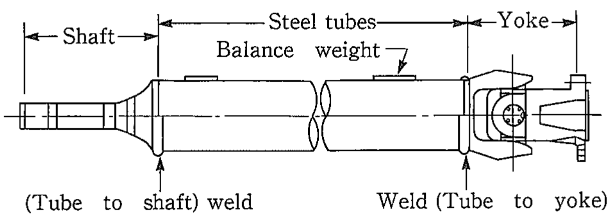


Fig. 3 Propeller shaft

3.1 Test Pieces

Electric resistance welded (ERW) steel tubes were used as test pieces. The properties of these test pieces are described in **Table 2**.

The tensile strength of the developed steel tube is 700~850 N/mm² grade.

3.2 Weldability

Both ends of the propeller shaft (steel tube) are applied by welding. There are two (**Photo 1**) welding methods : arc-welding and friction welding.

The hardness distributions of the welded portion are descibed in **Fig. 4**.

Softening at the heat affected zone (HAZ) in regards to the arc-welding method is slightly larger when compared to the friction welding method because of the difference in heat input.

3.3 Torsional Fatigue Properties

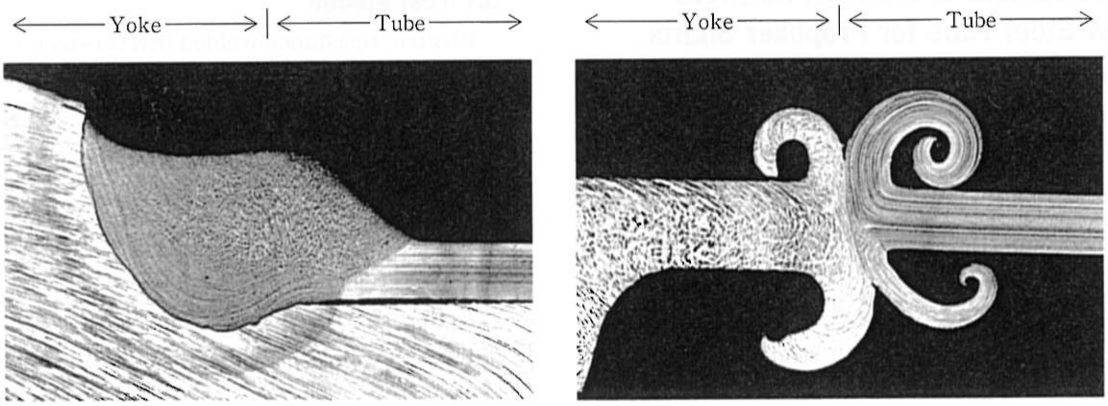
Torsional fatigue property is the most important concern when designing a propeller shaft. The authors have done torsional fatigue tests on test pieces produced by both arc-welding and friction-welding methods.

Test results described in **Fig. 5** show that the high strength steel tube has a longer service-life when compared to the 500 N/mm² grade conventional strength tube.

Table 2 Properties of test pieces

Type	Code No.	Manufacturing process		Chemical composition (%)						Tensile properties		
		Coil	Heat treatment	C	Si	Mn	Mo	Ti	Nb	YS (N/mm²)	TS (N/mm²)	El (%)
Conventional	50 H	Ⓗ	N/A	0.16	0.12	0.50	—	—	—	420	510	50
High strength (Developed)	70 H	Ⓗ	N/A	0.19	0.24	1.28	—	0.037	0.055	570	700	25
	70 C	©	SR	0.17	0.16	0.74	—	—	0.031	670	720	20
	80 C	©	SR	0.18	0.20	1.34	add	add	add	820	850	18

* Coil: Ⓗ Hot rolled, © Cold rolled * Tube size (mm): 65 $\phi \times 1.6$ t
* Heat treatment: N/A:Not applicable, SR: Stress relief



(Arc welding) (Friction welding)

Photo 1 Shape comparison at longitudinal section

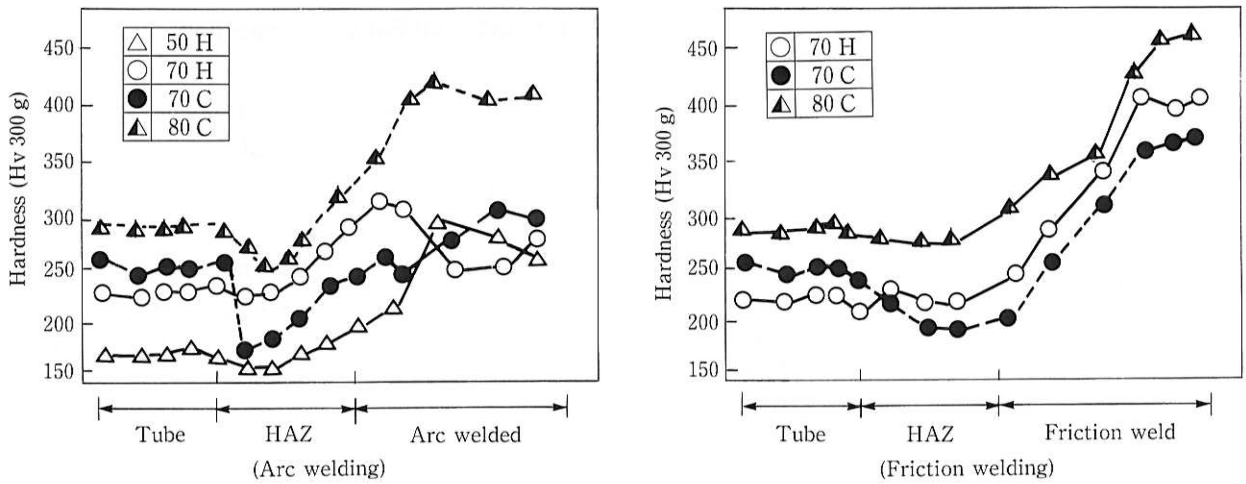


Fig. 4 Hardness distribution at longitudinal section

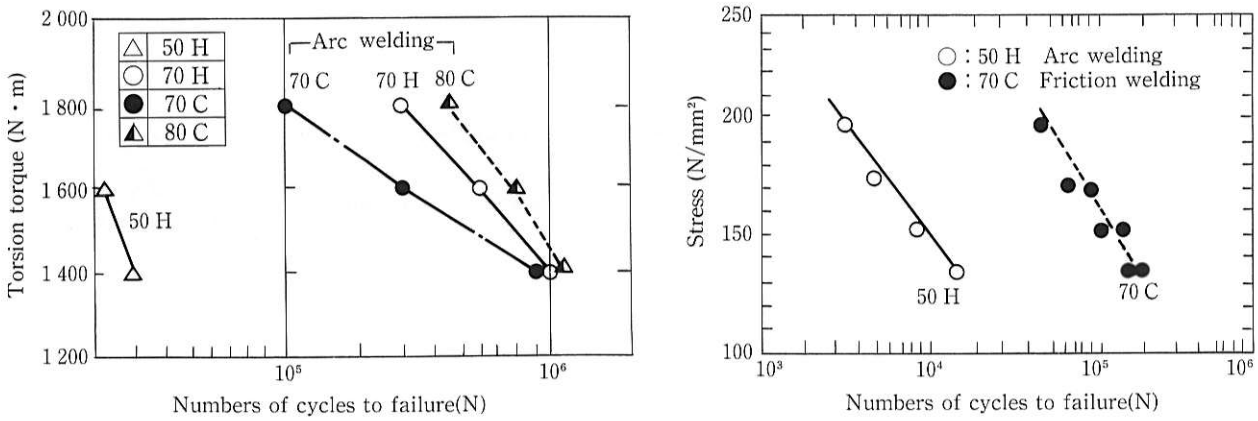


Fig. 5 Torsional fatigue test results (Completely reversed)

4. Side Door Beam

The automobile is a necessity in many communities nowadays, but the high level of fatal traffic accidents has become a critical issue with the public.

As a result, air bags and side door beams have been developed as a means of reducing fatalities. To protect an automobile passenger during side collisions, door reinforcements (side door beam) are employed (**Photo 2**). To ensure safety needs, while minimizing total car weight, steel tubes are the most obvious choice in providing side impact resistance.

The most important means of side door beam testing are as follows.

① 3-point static bending test
② Impact bending test
③ Delayed fracture test

This section introduces the properties of the side door beam for 1 500 N/mm² grade tensile strength tube.

4.1 Test Pieces

Electric resistance welded (ERW) steel tubes, manufactured with high frequency induction heating and quenching, were used as test pieces (**Table 3**).

4.2 Three-Point Bending Test

A schematic of the 3-point bending test method is shown in **Fig. 6**.

Figure 7 shows an example of bending load-displacement curves upon varied tube thickness. As shown in **Fig. 7**, bending load decreases after reaching the maximum point.

Furthermore, the bending load of a thinner tube

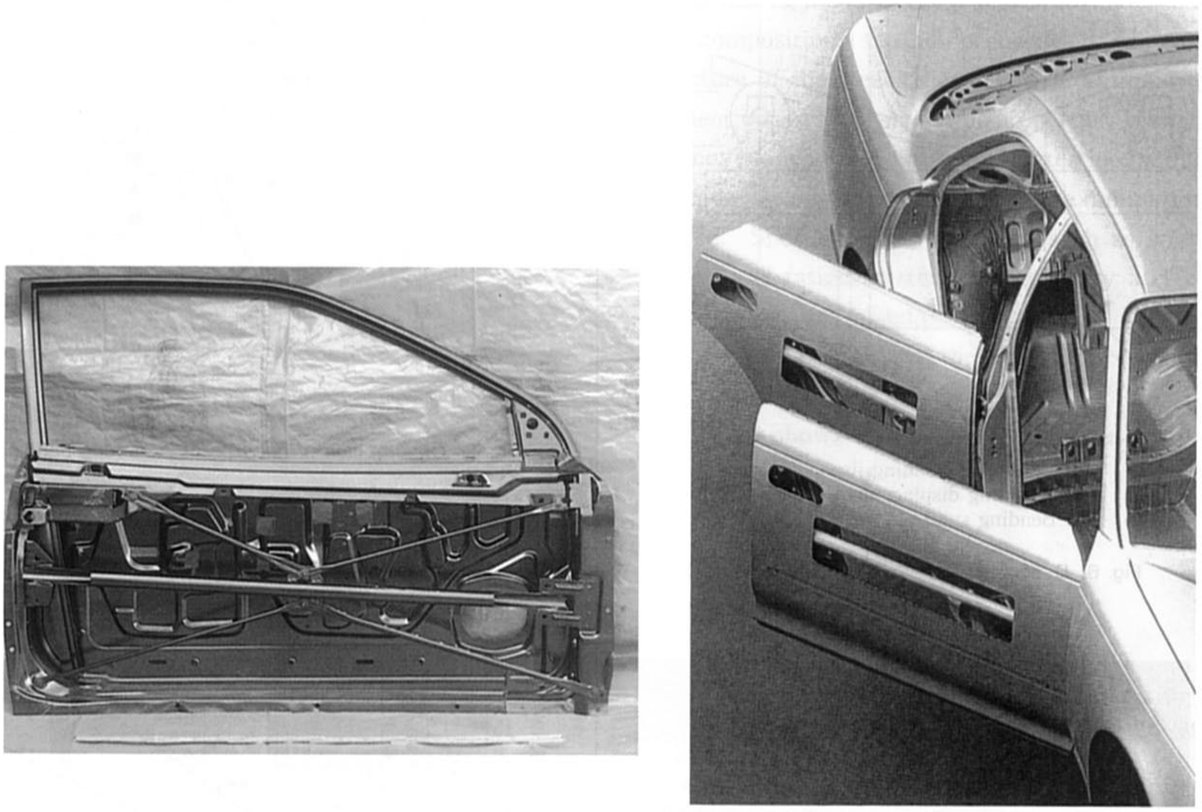


Photo 2 Application example of side door beam

Table 3 Properties of test pieces

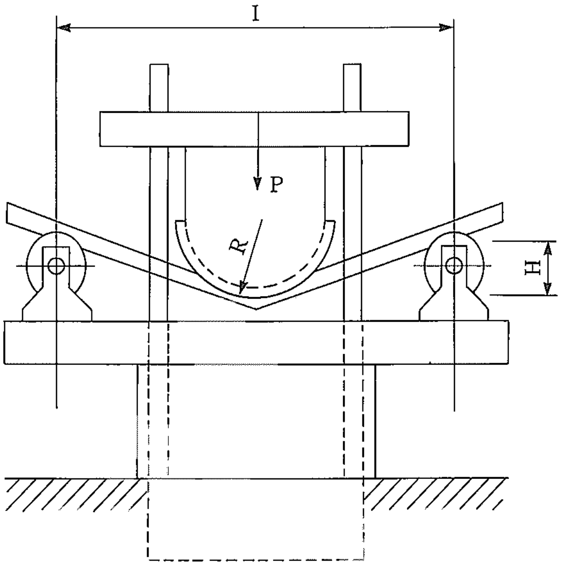
Chemical composition (%)						Tensile properties		
C	Si	Mn	Cr	Ti	B	YS (N/mm²)	TS (N/mm²)	El (%)
0.21	0.24	1.23	0.20	0.018	0.0014	1 300	1 550	14

will decrease rapidly because local buckling occurs.

Figure 8 shows the limit of local buckling. Local buckling tends to occur at approximately $t/d \leqq 8.5\%$, where t represents tube thickness and d represents the outside diameter of the tube.

Figure 9 shows data between the maximum bending load and the tensile strength of the tube. A good correlation of the maximum bending load is observed with regard to the tensile strength of the tube, and maximum bending load is inversely proportional to the bending span (**Fig.** 9).

The maximum bending load based on the results **Fig. 9** can be estimated by using the following mathematical equation.



P : Bending load
R : Radius of bending jig
H : Bending displacement
I : Bending span

Fig. 6 Bending test method for steel tube

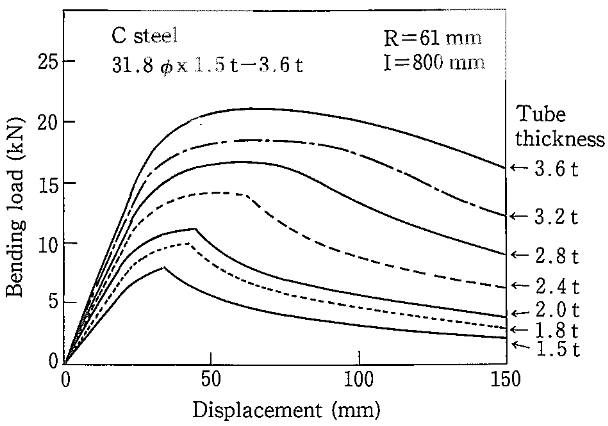


Fig. 7 Bending load-displacement curves upon varying tube thickness

$$Pcal = Sf \cdot Z \cdot \frac{K}{I}$$

$$Pcal = Sf \cdot \frac{\pi}{32} \cdot \frac{d^4-(d-2t)^4}{d} \cdot \frac{4}{I}$$

Where in, Pcal: Maximum bending load at calculation

Sf: Plastic flow stress = Tensile strength × 0.95 (supposed)

Z: Section modulus of tube

I: Bending span

K: Constant = 4 (3-point bending from both end supports)

d: Outside diameter of tube

t: Thickness of tube

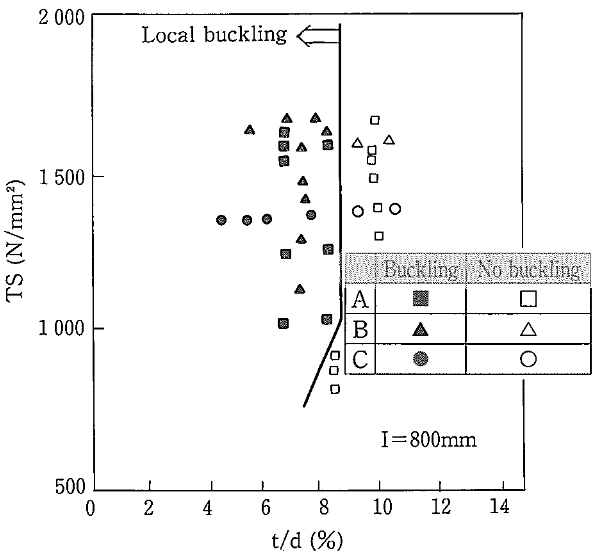
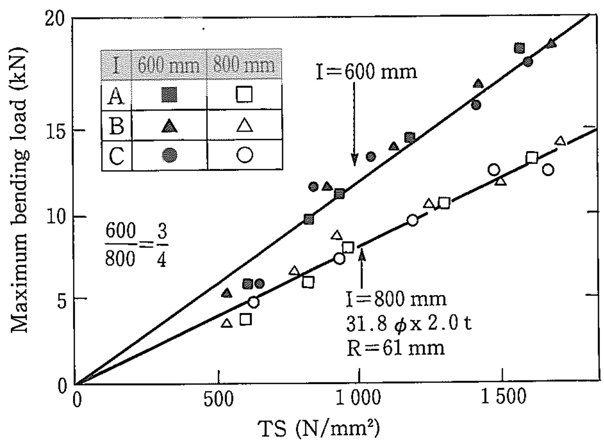


Fig. 8 General limit of buckling in steel tube bending



Varied TS are obtained by applying tempering heat treatment.

Fig. 9 Relationship between maximum bending load and TS

4.3 Impact Bending Test

The impact bending test is also applied to check the properties of side door beams.

The impact bending test is one of the simulations used to test cases in which there is an actual side collision. Test equipment and tube appearance after testing are shown in **Photos 3** and **4**.

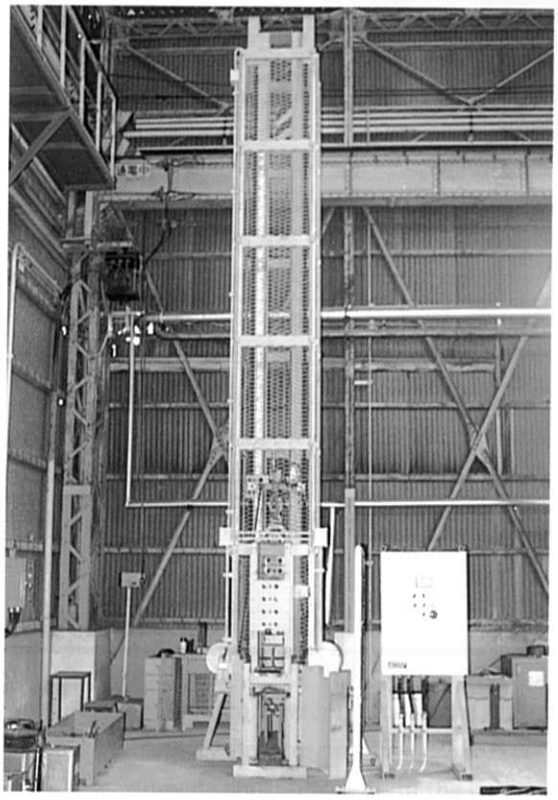
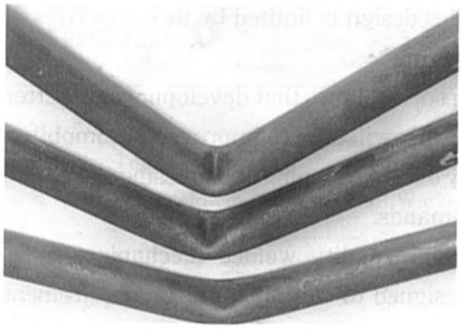


Photo 3 Impact bending test equipment



Fallen energy

4 900 J

4 400 J

3 530 J

- Tube size (mm): 31.8 $\phi \times 3.2$ t
- Bending radius R: 90 mm
- Bending span I: 430 mm

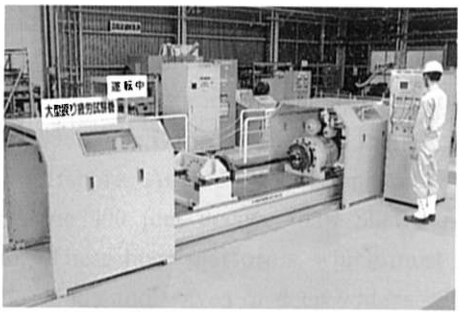
Photo 4 Tube appearance after impact bending test

5. Tube Evaluation Testing Facilities

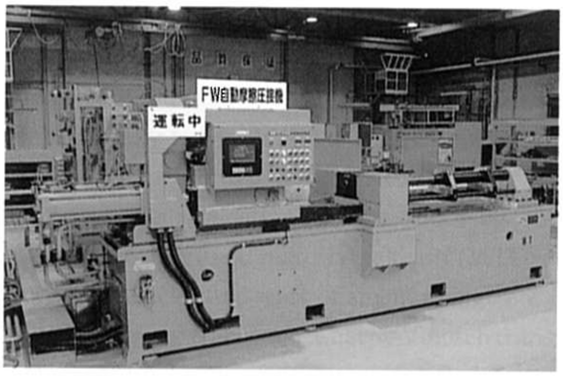
The testing facilities check and confirm the chemical composition, tensile properties and microstructure of the steel tubes. This is an important element in assessing steel tube properties. However, it is not enough to use only primary testing facilities, when developing new tubes. Further examination is needed. Special testing facilities, such as friction welder and fatigue tester, are necessary and very useful to test assembled parts.

The authors have used these facilities to get the data described in this report.

Photo 5 shows the testing facilities used in the previous evaluations.



(Torsional fatigue tester)



(Friction welder)

Photo 5 Testing facitilies

6. Conclusion

Automobiles design is limited by the properties of existing materials.

This being so, it follows that developing new better quality materials will lead to improved automobiles, which satisfy ever-developing and pressing social and economic demands.

Our new high quality welded mechanical tubes have been designed to comply with the requirement placed on automobile manufacturers to reduce weight and improve safety.

Junichi Tamaki

Staff Manager,
Welded Tube Quality Control Sec.
Wakayama Steel Works

Phone: 0734(54)4134

Reference

1) トヨタ技術(TOYOTA MOTOR Technical Report) Vol. 39(1989),26