Proceedings of the ASPF 2003 (The 8th Asian Symposium on Precision Forging), October 15 - 18, 2003

# The Bending minimization of Joint Shat in Cross rolling

**Park Joon Soo[1], *Lim Seong Joo[2], *Yoon Duk Jae[2], *Choi Seogou[2]**

[1] *Forging Dept. Bongshin Co, Incheon, South Korea*
[2] *Digital Production Processing Team, Manufacturing process Research Center, Korea Institute of Industrial Technology, South Korea*

## Abstract

Although cross rolling process has many advantages in forging a joint shaft, an automotive component of front axle unit, subsequent process is necessary to straighten its bending during forging process. In this paper the bending minimization of the joint shaft was studied to eliminate such an additional process.

First of all, a characteristic diagram was used to find out factors affecting the bending of the shaft. Also design of experiments was utilized for estimating the influence of those factors. It was found that the phase angle, which is the difference in starting positions between upper and lower dies, was important to minimize the bending of joint shaft and die cooling is necessary to diminish the distribution of bending.

Keyword: Cross rolling, Joint Shat, Bending, Heat treatment, Deformation, Characteristic diagram, Furnace

## 1. Introduction

A Crossroll process is a hot incremental forming method for producing long axi-symmetrical shafts which have one or more steps. A round heated billet inserted between upper and lower dies is progressively rolled as shown in Fig.1. It was reported that this process has following advantages [1,2]

- High productivity ; it is possible to produce 720 pieces for an hour.
- High precision; it is possible to produce forgings without flash and mismatch.
- Material savings ; On average, material utilization is 90% over.
- Long service life of die; Die life is at least 200,000 pieces.

In spite of these advantages, difficulty in the die design and the addition of sub-sequent process make it difficult to improve the quality and reduce the production cost. Especially in the case of forging joint shaft, it requires to be straightened when the bending amount in the middle of it is over 1mm because surface badness occurs on the shaft after machining. If it was straightened excessively, a heat treatment was necessary because of residual stresses in the shaft.

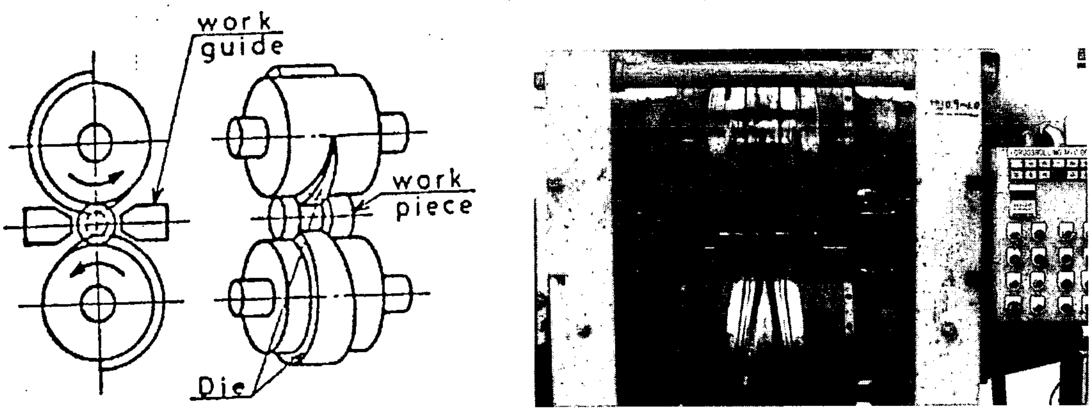
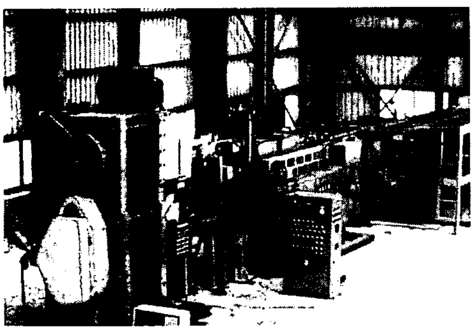



*Fig.1 The discipline of cross roll process*

Accordingly, the minimization of bending amount is essential for cost reduction. But studies in conjunction with the bending problem have not been enough till now.

## 2. Factors affecting the bending of joint shaft

Fig.2 shows the two-roll type cross rolling machine and its specifications [3] which was designed and manufactured by KITECH and Bongshin Co. Ltd.



| | |
|---|---|
| Roll diameter | ϕ 600 mm |
| Roll width | 600 mm |
| Max. speed rate of rolls | 6 rpm |
| Roll adjustment range | ±15mm |
| Stock diameter | ϕ 35~65mm |
| Main drive motor | 93 kw |
| Max. length of products | 430mm |
| Machine weight | 23 ton |

*Fig.2 Cross roll machine and the specifications*

Fig.3 shows the characteristic diagram of bending of joint shaft and subsequent process to straighten the bending occurred in the middle of it. It was found that the following factors affected the bending of joint shaft.

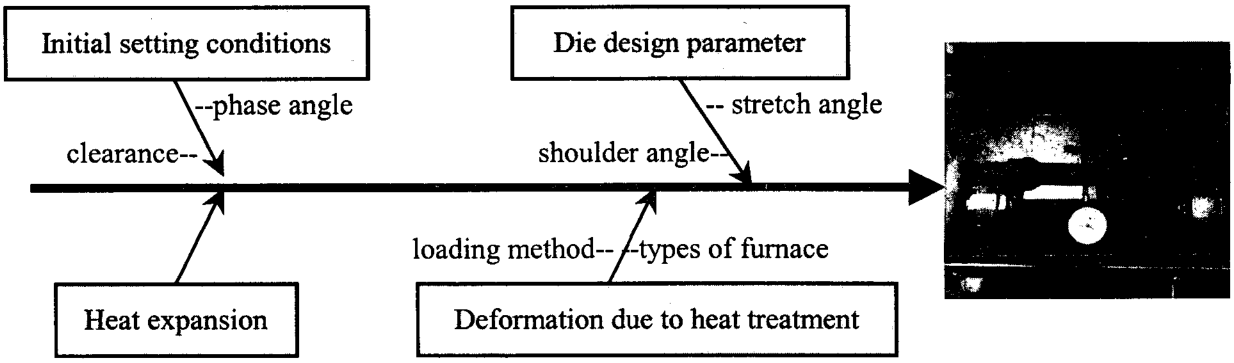



*Fig.3 The characteristic diagram for bending of joint shafts*

(1) Initial setting conditions: Two initial conditions must be set before forging starts. The one is phase angle and the other is the clearance between guides and round heated billet from inserting it into dies as shown in Fig.4.

(2) Heat expansion : Dimensions of dies and all the parts of cross rolling machine are expanded by heat because the round billet was heated up to 1100 ℃. For this reason, two initial setting conditions are gradually changed.

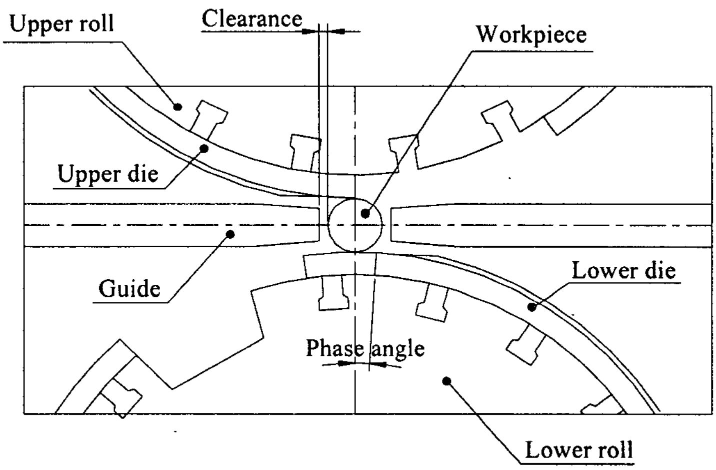



*Fig.4 The phase angle and clearance*

(3) Deformation due to heat treatment

Normalizing was performed according to the heat pattern in Fig.4 to improve machinability refine grain-structure of cross rolling forgings. Types of furnaces for normalizing affected the deformation during heat treatment.

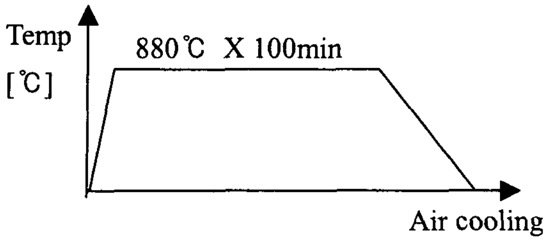



*Fig.5 Normalizing heat pattern*

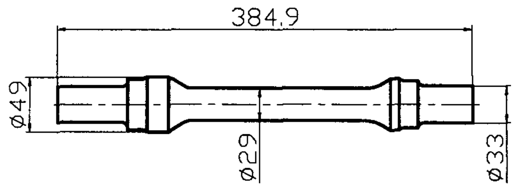



*Fig.6 The dimensions of joint shaft*

(4) Die design parameters: Parameters related to the shape of die also affected the bending, such as stretch angle or shoulder angle. 2)

## 3. Results

The research was carried out only about (1),(2) and (3) among above factors with regard to the bending of joint shaft in Fig.6.

### 3-1 Initial setting conditions

A experiment was carried out by two-way factorial design [4] in order to find out the influences of phase angle and clearance. It was recognized from table 1 and Fig.7 that the bending was minimized when phase angle was 0°, it means the starting point between upper and lower dies is synchronized, and the clearance was 1mm.

| B \ A | Repeat | A1 (0.5mm) | A2 (1mm) | A3 (1.5mm) | A4 (2mm) | Average of B level |
|---|---|---|---|---|---|---|
| B1 (0°) | 1 | 0.5 | 0.9 | 1.1 | 0.6 | 0.88 |
| | 2 | 1.0 | 1.2 | 1.2 | 0.4 | |
| | 3 | 0.8 | 0.7 | 1.4 | 0.8 | |
| B2 (1°) | 1 | 1.2 | 1.9 | 1.4 | 1.4 | 1.25 |
| | 2 | 0.9 | 0.6 | 0.9 | 1.6 | |
| | 3 | 1.2 | 1.4 | 1.2 | 1.3 | |
| B3 (2°) | 1 | 0.8 | 0.9 | 0.6 | 1.5 | 1.41 |
| | 2 | 1.7 | 0.9 | 1.8 | 1.6 | |
| | 3 | 1.9 | 1.4 | 2.0 | 1.8 | |
| Average of A level | - | 1.11 | 1.10 | 1.29 | 1.22 | - |

A: The levels of clearance
B:The levels of starting position difference

*Table 1 The results of two-way factorial design*

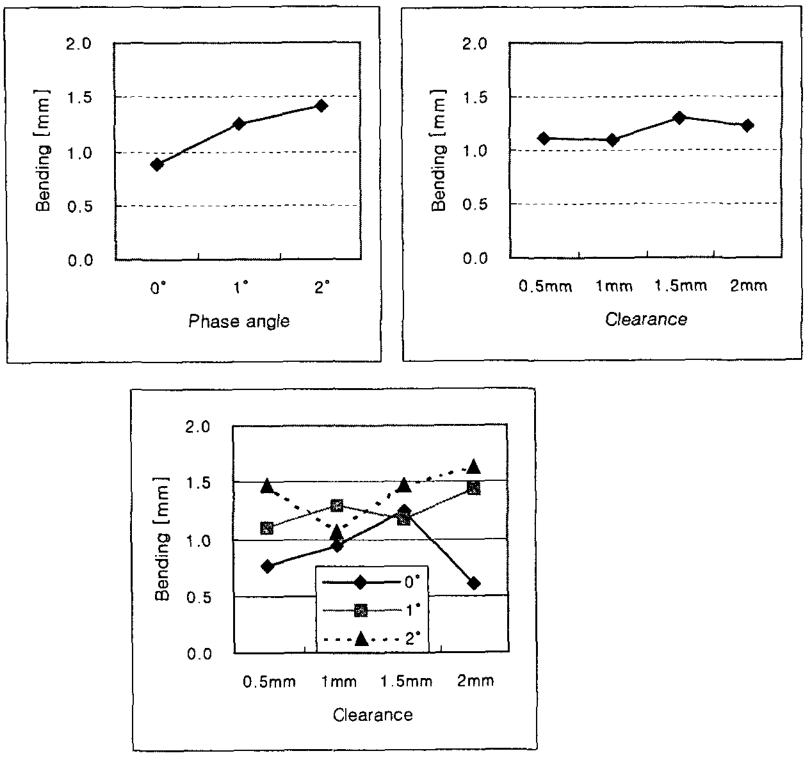



*Fig.7 The influences of phase angle and clearance*

It was recognized from table 2 that the phase angle is more significant than clearance and the interaction of these factors is not significant. However, there is no difference in dimension of joint shaft within upper levels

| Factors | Sum of squares | Degrees of freedom | Mean Square | $F_0$ | F estimation |
|---|---|---|---|---|---|
| A | 0.223 | 3 | 0.074 | 0.506 | F(3,24,0.05)=3.01 |
| B | 1.740 | 2 | 0.870 | $5.933^{**}$ | F(2,24,0.05)=3.4 |
| AXB | 1.152 | 6 | 0.192 | 1.309 | F(6,24,0.05)=2.51 |
| E | 3.52 | 24 | 0.146 | - | - |
| T | 6.636 | 35 | - | - | - |

.A: clearance .B: phase angle, .AXB: interaction between clearance and phase angle, .E: Error .T : Total,

Table 2 ANOVA (Analysis of Variances) of two-way factorial design[4)]

## 3-2 Heat expansion

Two experiments were carried out to estimate the effect of die cooling. Dies were not cooled in the first case while those were cooled by sprinkling water on the surfaces of dies at a rate of 0.6 liters per minute in the second case. The initial clearance and phase angle were set on 2mm and 0°. 1,100 forgings were produced and 160 forgings were sampled to measure the bending amount in each case. 90 pieces were taken from 1 to 90 forgings and 10 pieces were taken for every hundreds from 500 to 1,100 forgings . It was recognized from Fig.8 that die cooling diminished the width of bending distribution. The clearance after 300 forgings remained 1.7mm due to die cooling.

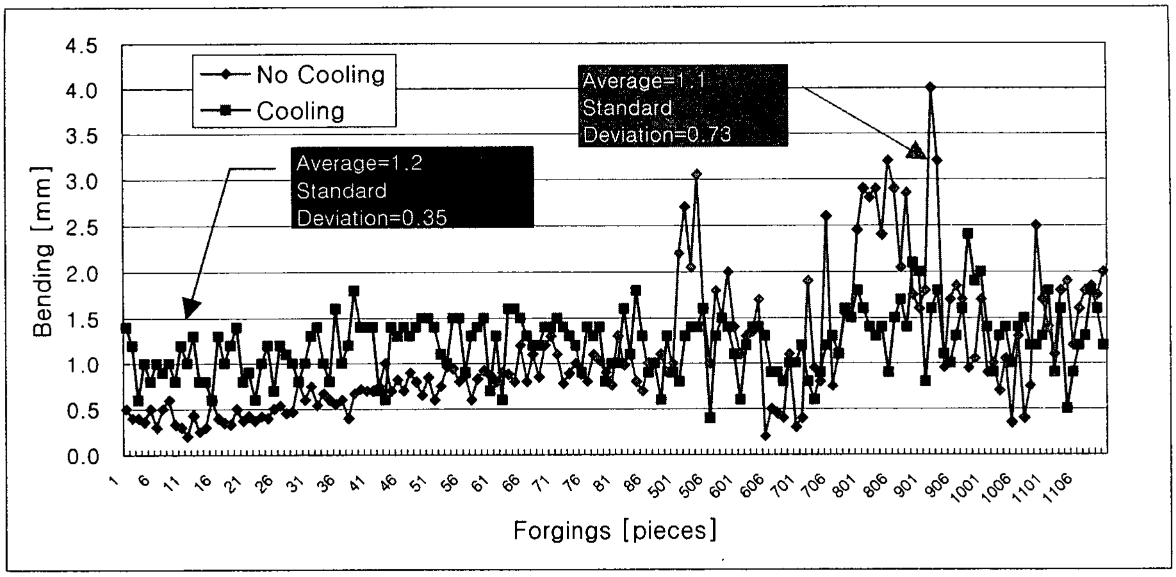



Fig.8 The effect of die cooling

## 3-3 Deformation due to heat treatment

In case of joint shaft, normalizing was performed after cross rolling in the pusher type continuous furnace or meshbelt type continuous furnace as shown in Fig.9 and Fig.10 respectively. Fig.9 shows the pusher type furnace with 6m in length and has three gas burners at both sides and the shape of multy-layer loading. Fig.10 shows meshbelt type continuous furnace with 10m in length which is electrically heated and the shape of two-layer loading.

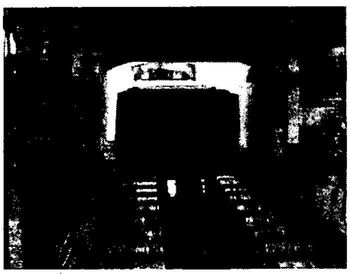


*Fig.9 Pusher type continuous furnace*

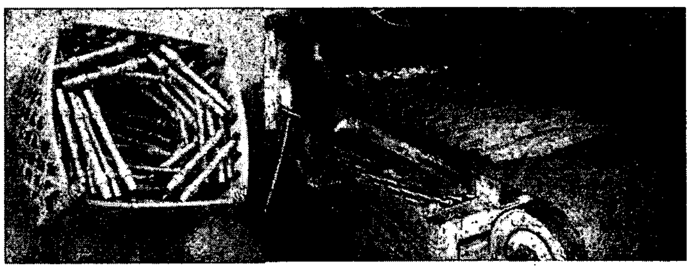
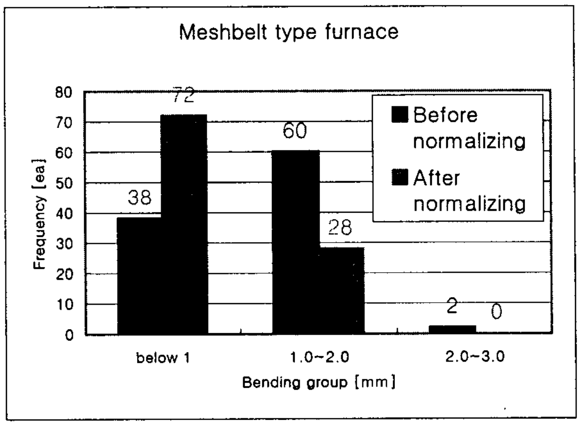


*Fig.10 Meshbelt type continuous furnace*

The deformation during heat treatment in two types furnace was estimated by measuring the bending amount of joint shaft before and after normalizing. 100 crossroll forgings were normalized and measured in both furnaces. It was recognized from Fig.11 that meshbelt type furnace is suitable for normalizing because the frequencies satisfying the bending spec (below 1mm) after normalizing is large. This is due to the fact that the temperature in the furnace remained constant and only two-layer loading was adopted. It was also found that two-layer loading in meshbelt type furnace did not affect the deformation during heat treatment.



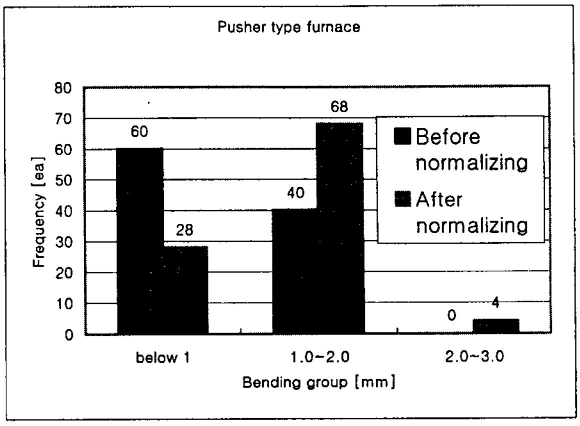




*Fig.11 The heat treating deformation of two types furnace*

## 4. Conclusions

As a result following conclusions were obtained from the research about bending minimization of joint shaft by using characteristic diagram and design of experiments

(1) In two-roll type cross rolling machine, the influence of phase angle is more significant than that of clearance.

(2) The distribution of bending of joint shaft was diminished by die cooling.

(3) The meshbelt type continuous furnace is suitable for normalizing joint shaft and two layer loading did not affect the deformation during heat treatment.

(4) The factors which affect the bending of joint shaft can be estimated quantatively and expenses and time for experiments were reduced epochally by using design of experiments.

The authors believe that subsequent research about die design parameters and clearance make it possible to eliminate subsequent process of straightening the bending of joint shaft.

## 5. References


1) Hidehiko Tsukamoto, Kazuo Morimoto and Tadayoshi Juge, "Application Study on Cross Roll Method for Axi-symmetrical Stepped Shaft",pp936-941,Proc.1st ICTP (1984), Japan. .

2) F.Neuberger, L. Möckel and L. Rötz, ."Transverse rolling", pp279-284,Metal Forming ,1968.

3) Park Joon Soo, Choi Seogou and Na Kyoung Hwan , "The Application of Cross Roll Process for forging Joint Shaft",pp85-93, 5th Forging Symposium (2000), South Korea.

4) Park Seong Hyun, "Design of experiments",pp150-154,1998.