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RESEARCH ON THE IMPROVEMENT OF FORGEABILITY OF SNCM STEEL

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Abstract

This research represents enhancement of forgeability of SNCM522H steel. Output Shaft (OP Shaft) has been used as a subject for the study. OP Shaft is used as component of power train for automobiles. To develop 1 pass cold forging process instead of existing 2 pass process for OP Shaft, studies in terms of process design and heat treatment were performed. To verify the new process, CAE simulations were performed. And hardness test, microstructural analysis and tensile tests after heat treatment were carried out to evaluate the validity of proposed heat treatment cycle. The 2 pass forging process could be reduced as 1 pass process through improvement of process and heat treatment cycle.

Keywords: Cold Forging, Forgeability, Output(OP) Shaft, Heat Treatment, CAE

1. Introduction

Production by forging processes has been one of the most critical manufacturing methods in automotive component industries. Among the forging processes, cold forging processes have been widely used for near-net-shape producing without machining. [1 ~ 2]

However in cold forging processes, when metal is subjected to high plastic deformation in room temperature, working limit may be limited by ductile fracture, e.g. the occurrence of crack in the workpiece. This limit of workability acts against improvement of productivity.

Output shaft (OP shaft) which is used as component of power train for automobile have been produced by 3 stages of cold forging processes. But due to the low forgeability of SNCM steel, raw material of OP shaft, one more heat treatment have to be conducted to relieve the stress after first 2 stages of cold forging.

To improve this situation, studies in terms of process design and heat treatment were performed. To verify the new process, CAE simulations were performed. And hardness test, microstructural analysis and tensile tests after heat treatment were carried out to evaluate the validity of proposed heat treatment cycle.

2. Development of forging processes

Chemical compositions of raw material of OP shaft, SNCM522H steel are shown in Table 1. And current cold forging process for OP shaft is shown in Fig. 1. The surface crack is occurred when current process applied to SNCM522H steel as shown in Fig. 2.

Table 1 Chemical composition of SNCM522H (wt%)

C	Si	Mn	P	S	Ni	Cr	Mo	Cu	Nb
0.21	0.05	0.57		0.10	1.0	0.45	0.70		0.15
~0.24	~0.15	~0.67	~0.25	~0.20	~1.1	~0.60	~0.80	~0.25	~0.25

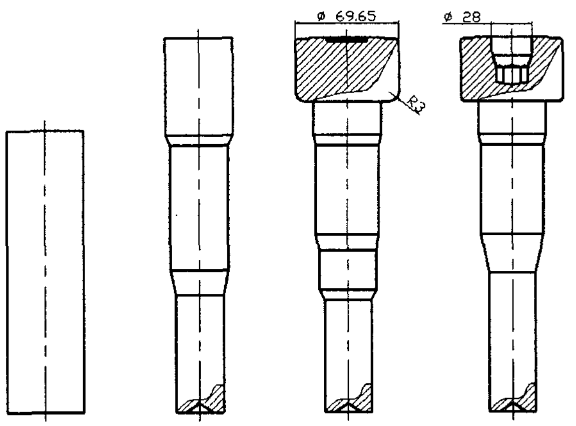


Fig. 1 Current cold forging process of OP shaft

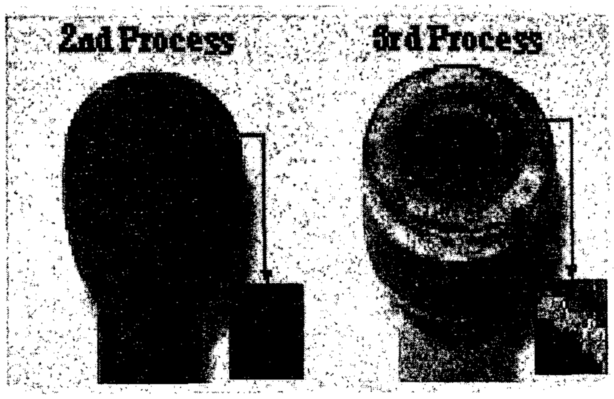


Fig. 2 The crack on the current process

To evaluate the causes of occurrence of crack in the 2nd and 3rd stages, CAE simulations were carried out by AFDEX 3D. In the 2nd stages, crack were occurred in the region of internal diameter of head (Fig. 3(a)) due to the exceeded tensile stress to the direction of circumference (Fig. 3(b)) during upsetting of head. And also in the 3rd stages, possibility of occurrence of crack is very high (Fig. 4(a)) due to the exceeded tensile stress to the direction of circumference and axis (Fig. 4(b)).

Usually cold forgeability is estimated by the history of hydrostatic pressures by the plastic deformation paths. [3~4] As shown in Fig. 4(b), crack can be occurred easily by the ductile fracture if the tensile(+) hydrostatic pressure would occurred.

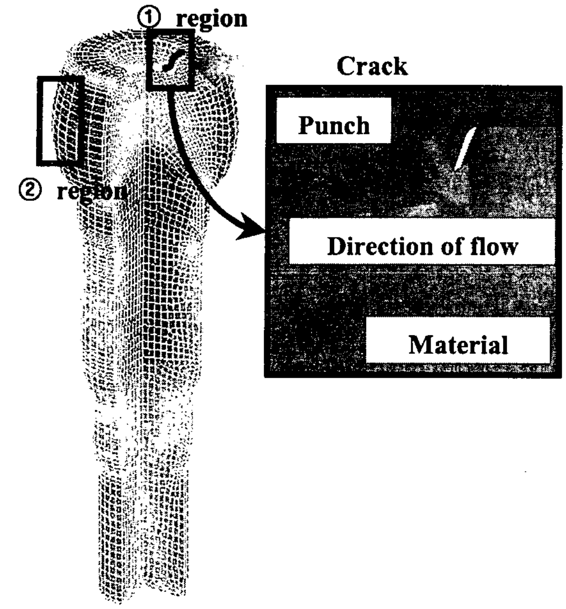


Fig. 3(a) CAE results of 2nd process

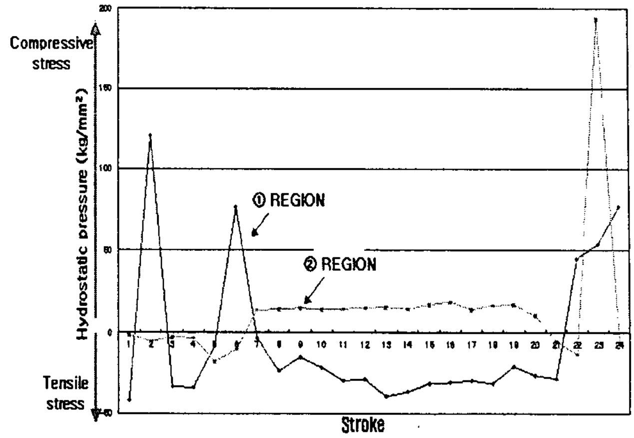


Fig. 3(b) Hydrostatic stress vs. stroke in 2nd process

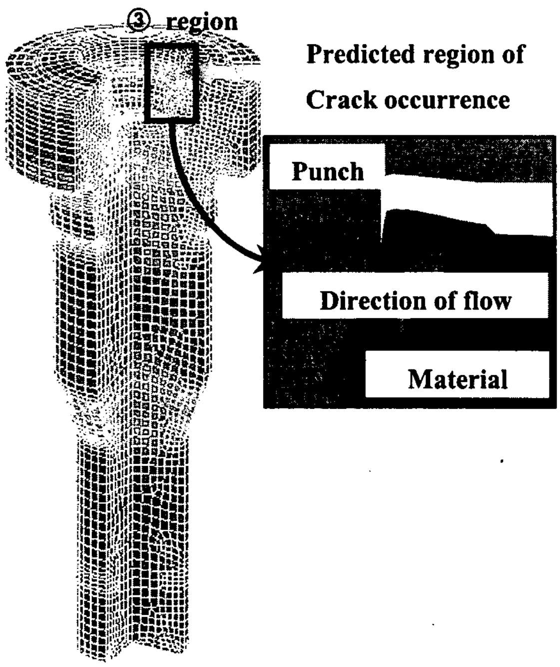


Fig. 4(a) CAE results of 3rd process

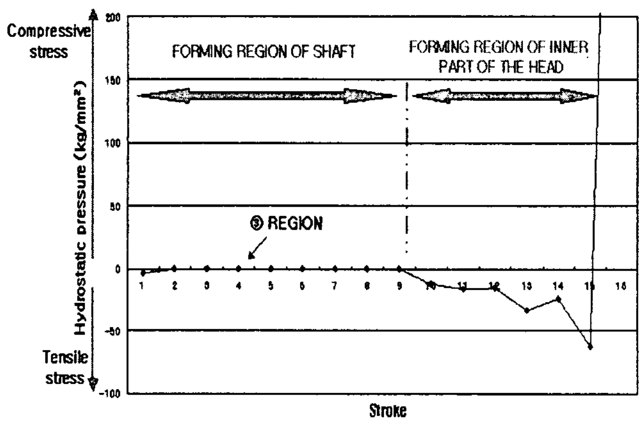


Fig. 4(b) Hydrostatic stress vs. stroke in 3rd process

To improve these problems, during forming of the region of internal diameter of head (Fig. 3(a) ① region), restrictions for the region of outer diameter were decreased by increasing the outer diameter of dies (Fig. 3(a) ② region) and the radius of curvature of bottom side of dies. And in the 3rd process, dimensions of mandrel were shortened to reduce plastic deformation of the region of internal diameter. The improved process is shown in Fig. 5.

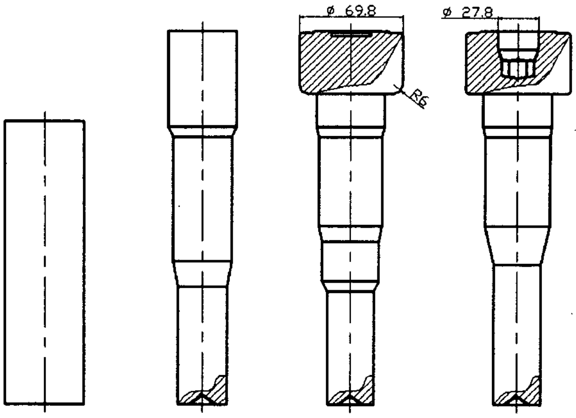


Fig. 5 Improved cold forging process of OP shaft

3. Development of heat treatment cycle

3.1 Spherodizing annealing cycle

Proposed heat treatment cycle are shown in Fig. 6. A1 temperature of SNCM steel is 713℃ and A3 temperature is 805℃. So first heat treatment cycle was selected to keep in 760℃, middle temperature of A1 and A3, and below A1 temperature most times (Fig. 6(a)). But for the first proposed cycle, the microstructure was coarse due to the high temperature. So the temperature was changed to 730℃ in second proposed heat treatment cycle (Fig. 6(b)). And the time maintained near 713℃ were extended for more spherodizing in third proposed cycle.

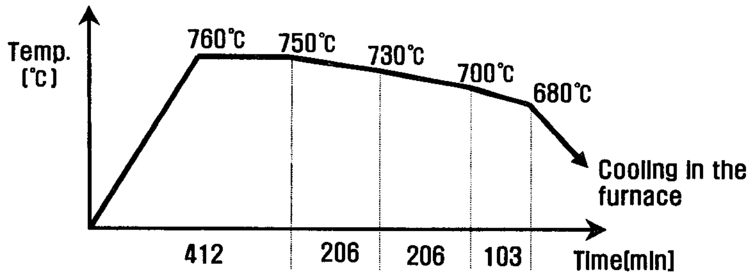


Fig. 6(a) Proposed heat treatment cycle – (1)

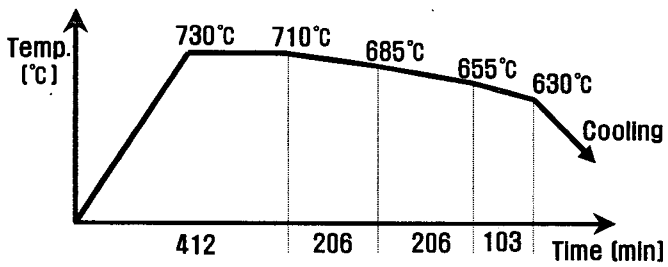


Fig. 6(b) Proposed heat treatment cycle – (2)

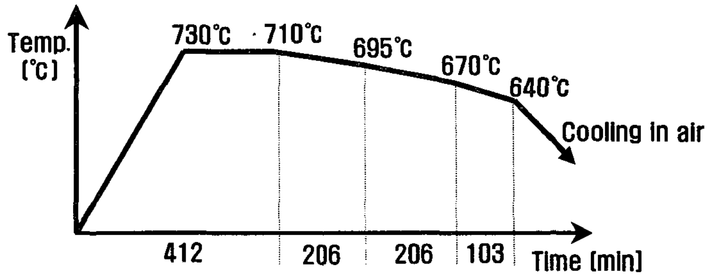


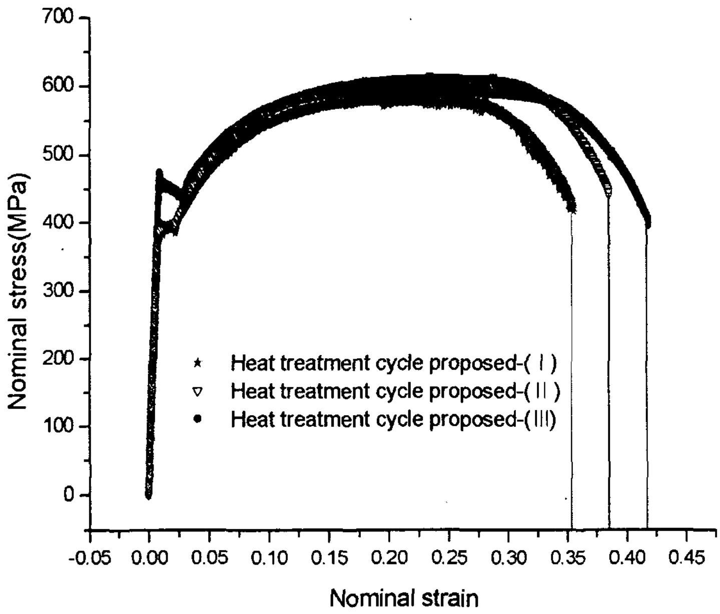
Fig. 6(c) Proposed heat treatment cycle – (3)

3.2 Experiments and results

Tensile tests, hardness tests and microstructure analysis were performed to verify the validity of proposed heat treatment cycle. Results of hardness tests are shown in Table 2. Results of tensile tests are shown in Fig. 7 and results of microstructure analysis are Fig. 8.

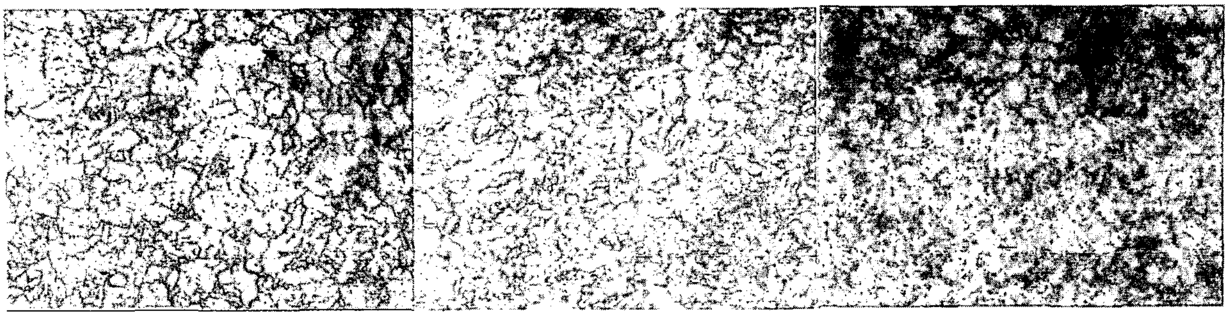
Table 2 Results of hardness tests (HRB)

	1	2	3	4	5	Avg.
Cycle 1	89.9	82.3	82.1	83.1	83.5	84.2
Cycle 2	88.2	87.6	86.4	86.7	87.2	87.2
Cycle 3	86.6	86.1	85.2	84.8	85.7	85.7



Cycle	1	2	3
Elongation	0.355	0.375	0.44

Fig. 7 Results of tensile tests



(a) Cycle 1 (×400) *(b) Cycle 2 (×400)* *(c) Cycle 3 (×400)*

Fig. 8 Results of microstructure analysis

As shown in Table 2, hardness of cycle 1, which heat treatment temperature is the highest, is the lowest. But, the elongation was improved remarkably in cycle3 (Fig. 7). And also spherodizing of cycle 3 is better than those of cycle 1 and 2 (Fig. 8).

The validity of cycle 3 can be verified by above mentioned experiments results.

4. Conclusions

CAE simulations of cold forging process for OP shaft and spherodizing annealing treatment tests of SNCM522H steel were conducted to improve the foegeability of OP shaft. From this study, the following conclusions can be drawn.

(1) In the current process, tensile hydrostatic stress acts on the region of head during the forging process. So it is estimated that the possibility of occurrence of crack is very high. And this result could be checked in the actual manufacturing process.

(2) New spherodizing annealing treatment cycle for SNCM522H steel were proposed. Excellence of new cycle were verified by tensile, hardness and microstructure analysis.

(3) By the new process, OP shaft could be manufactured by 1 pass process. So the productivity and the die lives were improved considerably.

Reference

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