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Design of temperature separator with sensor on hot forging

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Abstract: *Hot forging is widely used in the manufacturing of automotive components. Upsetting dependent defects were identified for inconvenient of forging temperature on the forging of solid billet. The trials were carried out in the following billets sizes like M27, M28, M30, M36, and M42. This paper describes to reduce the number of defects in a forged component by design the temperature separator for ensuring the billet temperature between 1000-1200 °c during the hot forging operation. In this study, trial of temperature separator has been made for working condition and forging quality is compared. The defects were completely eliminated for M27, M28, M30 and M36 billets. The error percentage was reduced to 4 for the billet size M42.*

Keywords: Forging defects; Forging temperature; temperature separator; Trial

I. Introduction

During this century the growth of the forging industry has increase rapidly. This increase is mainly caused by the recent development of new and more advanced tools, improved materials and larger presses. Due to this, the competition between forging companies has on creased and today main objectives move towards right first time- products. This achievement in production requires lower scrap percentage, shorter lead times and less waste of money for the production of useless tools. To obtain this, a design support system for the prevention of common defects would of value. The necessity for the system is based on the designer's difficulties when trying to optimize the process by reducing the number of stages in the manufacturing process of the component During hot forging, the deviation of the preheating temperature of the billet was considered. The characteristics of the billet during electroplating or induction heating are very complex in the preheating process. Therefore, an induction heating of billet has become increasingly important as a means of reducing the heating time and an effective control of heating temperature. In this paper describes to reduce the number of defects in a forged component by design the temperature separator for ensuring the billet temperature between 1000-1200 °c during the hot forging operation. Here fully study about existing system and collect the relevant data's make the design for corresponding requirements.

II. Problem Description

Here during the forging did not maintain the proper temperature because in this work done by manually. So, defects are occurring such like infilling, inner cracks, improper grain flow and etc. The following temperatures are noted during the forging the billet at various billets size such like M27, M28, M30, M36, and M42. Here percentage of error can be calculated depended on unaccepted forging temperature. Percentage of error is varied from billet size. The table I show the initial forging conditions of the M27 billet.

TABLE I. M27 BILLET – INITIAL CONDITION

S.No	Forging Temperature in °C	Forging time per billet in sec
1	1098	10
2	1105	10
3	1089	10
4	1103	10
5	1076	10
6	1099	10
7	1050	10
8	1045	10
9	1110	09
10	0988	10
11	1046	10
12	1101	10
13	1143	10

14	0999	09
15	1120	10
16	1104	10
17	1099	10
18	0899	10
19	1054	09
20	1103	10
21	1100	10
22	1089	09
23	0879	10
24	1000	10
25	1078	10

The percentage of error is calculated using the following formula. The number of trials which has unacceptable forging temperature is 4. The total number of forgings done was 25.

$$\text{Percentage of error} = \frac{\text{number of unacceptable forging temperature}}{\text{total number of forging temperature}} * 100$$

$$\text{Percentage of error} = \frac{4}{25} * 100$$

$= 16\ \%$

TABLE II

M28 BILLET – INITIAL CONDITION

S.No	Forging Temperature in °C	Forging time per billet in sec
1	1101	11
2	1110	11
3	1099	11
4	1111	11
5	1099	11
6	1102	10
7	0987	11
8	1099	11
9	1107	11
10	1109	11
11	1134	09
12	1000	11
13	1150	11
14	1098	11
15	1132	09
16	0895	11
17	1109	11
18	1100	11
19	1099	11
20	1087	09
21	0989	09
22	0976	11
23	1170	11
24	1145	11
25	1113	11

The percentage of error is calculated using the following formula. The number of trials which has unacceptable forging temperature is 5. The total number of forgings done was 25.

$$\text{Percentage of error} = \frac{\text{number of unacceptable forging temperature}}{\text{total number of forging temperature}} * 100$$

$$\text{Percentage of error} = \frac{5}{25} * 100$$

$= 20\ \%$

TABLE III
M30 BILLET – INITIAL CONDITION

S.No	Forging Temperature in °C	Forging time per billet in sec
1	1134	12
2	1123	12
3	1101	12
4	1145	12
5	1123	12
6	1099	09
7	0967	09
8	0987	09
9	0934	12
10	1176	12
11	1189	12
12	1145	12
13	1098	12
14	1093	12
15	1105	09
16	0899	09
17	0999	12
18	1198	12
19	1134	12
20	1154	12
21	1123	12
22	1094	09
23	0983	09
24	0994	12
25	1120	12

The percentage of error is calculated using the following formula. The number of trials which has unacceptable forging temperature is 7. The total number of forgings done was 25.

$$\text{Percentage of error} = \frac{\text{number of unacceptable forging temperature}}{\text{total number of forging temperature}} * 100$$

Percentage of error $= \frac{7}{25} * 100$

$= 28\,\%$

TABLE IV
M36 BILLET – INITIAL CONDITION

S.No	Forging Temperature in °C	Forging time per billet in sec
1	1123	15
2	1134	15
3	1145	15
4	1156	15
5	1167	15
6	1145	15
7	1178	15
8	1100	15
9	1167	15
10	1109	15
11	1123	15
12	1134	15
13	1122	15
14	1136	15
15	1123	15
16	1167	15

17	1145	15
18	0991	10
19	0987	10
20	1156	15
21	1167	15
22	1198	15
23	1145	15
24	1165	15
25	1123	15

The percentage of error is calculated using the following formula. The number of trials which has unacceptable forging temperature is 9. The total number of forgings done was 25.

$$\text{Percentage of error} = \frac{\text{number of unacceptable forging temperature}}{\text{total number of forging temperature}} * 100$$

Percentage of error $= \frac{9}{25} * 100$

$= 36\ \%$

TABLE V

M42 BILLET – INITIAL CONDITION

S.No	Forging Temperature in °C	Forging time per billet in sec
1	1123	15
2	1134	15
3	1145	15
4	1156	15
5	1167	15
6	1145	15
7	1178	15
8	1100	15
9	1167	15
10	1109	15
11	1123	15
12	1134	15
13	1122	15
14	1136	15
15	1123	15
16	1167	15
17	1145	15
18	0991	10
19	0987	10
20	1156	15
21	1167	15
22	1198	15
23	1145	15
24	1165	15
25	1123	15

The percentage of error is calculated using the following formula. The number of trials which has unacceptable forging temperature is 2. The total number of forgings done was 25.

$$\text{Percentage of error} = \frac{\text{number of unacceptable forging temperature}}{\text{total number of forging temperature}} * 100$$

Percentage of error $= \frac{2}{25} * 100$

$= 8\ \%$

III. Design of temperature separator

The temperature separator consists of pneumatic cylinder, solenoid, supporting beam and pneumatic connection. These arrangements are depending on the following parameters and design calculations.

- Forging temperature
- Cylinder thrust
- Billet diameter
- Air consumption
- Billet flow time
- Length of billet
- Weight of billet
- Billet heating time

The temperature separator is shown in Figure 1. In this temperature separator is arranged by Double acting cylinder, Solenoid, Pressure gauge, supporting beam.

Fig. 1 Temperature separator

A. *Calculations*

The following calculation is used to design a temperature separator and also used to proper working condition. The following data can used to calculate the thrust force, air consumption.

TABLE I
COLLECTED DATA FOR CALCULATION

Description	Value
Cylinder A diameter of piston in cm	5.5
Cylinder A diameter of piston rod in cm	2.0
Stroke length of cylinder A	63.0
Cylinder B diameter of piston in cm	2.5
Cylinder B diameter of piston rod in cm	1.0
Stroke length of cylinder B	15.4
Cylinder C diameter of piston in cm	2.5
Cylinder C diameter of piston rod in cm	1.0
Stroke length of cylinder C	15.4
operating air pressure in bar	5.6
Stroke time in sec	0.5

A. Cylinder thrust

The following formula used to calculate the cylinder thrust for double acting cylinder.
Forward stroke

$$F = \frac{\pi}{4}D^2P$$

Return stroke

$$F = \frac{\pi}{4}(D^2 - d^2)P$$

Where,

F= cylinder thrust in kg

D= diameter of piston in cm

d= diameter of piston rod in cm

P= operating air pressure in bar

Cylinder thrust for cylinder A:

Forward stroke

$$F_A = \frac{\pi}{4}D^2P$$

$$= \frac{\pi}{4} * 5.5^2 * 5.6$$

= 132.97 Kgs

Return stroke

$$F_A = \frac{\pi}{4}(D^2 - d^2)P$$

$$= \frac{\pi}{4} * (5.5^2 - 2^2) * 5.6$$

= 115.39 Kgs

Cylinder thrust for cylinder B:

Forward stroke

$$F_B = \frac{\pi}{4}D^2P$$

$$= \frac{\pi}{4}\, 2.5^2 * 5.6$$

= 27.47 Kgs

Return stroke

$$F_B = \frac{\pi}{4}(D^2 - d^2)P$$

$$= \frac{\pi}{4} * (2.5^2 - 1^2) * 5.6$$

=23.07 Kgs

Here cylinder B and cylinder C are same specification so, cylinder thrust of cylinder C is same as cylinder B.

B. *Air consumption*

The air consumption data for a cylinder is required to estimate the compressor capacity. The calculations include air consumption during forward as well as return stroke.

Forward stroke

$$C = \left[\frac{\pi}{4}D^2(P+1)L\right]/1000$$

Return stroke

$$C = \left[\frac{\pi}{4}(D^2 - d^2)(P+1)L\right]/1000$$

Air consumption for cylinder A

Forward stroke

$$C_A = \left[\frac{\pi}{4}D^2(P+1)L\right]/1000$$

$$= \left[\frac{\pi}{4}5.5^2(5.6+1)63\right]/1000$$

=9.873 ltrs

Return stroke

$$C_A = \left[\frac{\pi}{4}(D^2 - d^2)(P+1)L\right]/1000$$

$$= \left[\frac{\pi}{4}(5.5^2 - 2^2)(5.6+1)63\right]/1000$$

=8.568 ltrs

Air consumption for cylinder B
Forward stroke

$$C_B = \left[\frac{\pi}{4} D^2 (P+1) L\right] / 1000$$

$$= \left[\frac{\pi}{4} 2.5^2 (5.6+1) 15.4\right] / 1000$$

=0.498 ltrs

Return stroke

$$C_B = \left[\frac{\pi}{4} (D^2 - d^2)(P+1) L\right] / 1000$$

$$= \left[\frac{\pi}{4} (2.5^2 - 1^2)(5.6+1) 15.4\right] / 1000$$

=0.419 ltrs

Here cylinder B and cylinder C are same specification so, Air consumption of cylinder C is same as cylinder B.

IV. Result and Discussion

The following data's are noted from new arrangement of temperature separator. Such a data's are noted billet temperature, new system working condition and heating time for M27, M28, M30, M36, and M42.

TABLE I
M27 BILLET –FINAL CONDITION

The trials were conducted on the M27 billets. The heating time was 10 seconds. The system condition remained the ok throughout these trials.

S.NO	BILLET TEMPERATURE IN °C	SYSTEM CONDITION	HEATING TIME PER BILLET (Sec)
1	1123	OK	10
2	1054	OK	10
3	1109	OK	10
4	1067	OK	10
5	1134	OK	10
6	1165	OK	10
7	1056	OK	10
8	1145	OK	10
9	1132	OK	10
10	1132	OK	10
11	1145	OK	10
12	1134	OK	10
13	1154	OK	10
14	1095	OK	10
15	1123	OK	10
16	1143	OK	10
17	1165	OK	10
18	1098	OK	10
19	1089	OK	10
20	1094	OK	10
21	1095	OK	10
22	1124	OK	10
23	1098	OK	10
24	1145	OK	10
25	1120	OK	10

TABLE II
M28 BILLET –FINAL CONDITION

The trials were conducted on the M28 billets. The heating time was 11 seconds. The system condition remained the ok throughout these trials and the forging temperatures are within the acceptable level.

S.NO	BILLET TEMPERATURE IN °C	SYSTEM CONDITION	HEATING TIME PER BILLET (Sec)
1	1114	OK	11
2	1137	OK	11
3	1100	OK	11
4	1130	OK	11
5	1140	OK	11
6	1132	OK	11
7	1099	OK	11
8	1143	OK	11
9	1147	OK	11
10	1127	OK	11
11	1145	OK	11
12	1113	OK	11
13	1150	OK	11
14	1190	OK	11
15	1160	OK	11
16	1129	OK	11
17	1113	OK	11
18	1152	OK	11
19	1172	OK	11
20	1149	OK	11
21	1153	OK	11
22	1124	OK	11
23	1098	OK	11
24	1145	OK	11
25	1120	OK	11

TABLE III
M30 BILLET –FINAL CONDITION

The trials were conducted on the M30 billets. The heating time was 12 seconds. The system condition remained the ok throughout these trials and the forging temperatures are within the acceptable level.

S.NO	BILLET TEMPERATURE IN °C	SYSTEM CONDITION	HEATING TIME PER BILLET (Sec)
1	1145	OK	12
2	1092	OK	12
3	1129	OK	12
4	1105	OK	12
5	1113	OK	12
6	1116	OK	12
7	1102	OK	12
8	1127	OK	12
9	1114	OK	12
10	1118	OK	12
11	1125	OK	12
12	1140	OK	12
13	1157	OK	12

14	1125	OK	12
15	1147	OK	12
16	1111	OK	12
17	1114	OK	12
18	1097	OK	12
19	1126	OK	12
20	1107	OK	12
21	1117	OK	12
22	1114	OK	12
23	1103	OK	12
24	1088	OK	12
25	1147	OK	12

TABLE IV
M36 BILLET –FINAL CONDITION

The trials were conducted on the M36 billets. The heating time was 12 seconds. The system condition remained the ok throughout these trials and the forging temperatures are within the range of acceptable level.

.S.NO	BILLET TEMPERATURE IN °C	SYSTEM CONDITION	HEATING TIME PER BILLET (Sec)
1	1100	OK	12
2	1092	OK	12
3	1129	OK	12
4	1105	OK	12
5	1104	OK	12
6	1109	OK	12
7	1102	OK	12
8	1127	OK	12
9	1114	OK	12
10	1118	OK	12
11	1156	OK	12
12	1140	OK	12
13	1157	OK	12
14	1125	OK	12
15	1147	OK	12
16	1134	OK	12
17	1115	OK	12
18	1165	OK	12
19	1126	OK	12
20	1123	OK	12
21	1117	OK	12
22	1114	OK	12
23	1103	OK	12
24	1123	OK	12
25	1147	OK	12

TABLE V
M42 BILLET –FINAL CONDITION

The trials were conducted on the M42 billets. The heating time was 15 seconds. The system condition remained the ok throughout these trials.

S.NO	BILLET TEMPERATURE IN °C	SYSTEM CONDITION	HEATING TIME PER BILLET (Sec)
1	1179	OK	15
2	1159	OK	15
3	1141	OK	15
4	1130	OK	15
5	1260	OK	15
6	1165	OK	15
7	1170	OK	15
8	1183	OK	15
9	1195	OK	15
10	1178	OK	15
11	1186	OK	15
12	1196	OK	15
13	1174	OK	15
14	1130	OK	15
15	1150	OK	15
16	1165	OK	15
17	1173	OK	15
18	1169	OK	15
19	1194	OK	15
20	1189	OK	15
21	1165	OK	15
22	1194	OK	15
23	1189	OK	15
24	1165	OK	15
25	1188	OK	15

From the above temperature values are suitable for forging without defects and system conditions are properly worked but M40 billet only some error occurs. . The number of trials which has unacceptable forging temperature is 1. The total number of forgings done was 25.The following percentage error is there.

Percentage of error =

$$\frac{number\ of\ unacceptable\ forging\ temperature}{total\ number\ of\ forging\ temperature} * 100$$

Percentage of error $= \frac{1}{25} * 100$ $= 4\%$

The percentage of above billets such like M27, M28, M30, and M36 are completely reduced. The percentage of error for M42 billet is 36% during the normal forging steps but now reduced into 4% by new system of temperature maintainer. So if the billet size is increased, the number of rejection is likely to be increased.

The defects were completely eliminated for M27, M28, M30 and M36 billets. The error percentage was reduced to 4 for the billet size M42. This is because when the size of the billet increases, it is difficult to maintain the temperature in the induction heater. The grain size increases when the forging temperature decreases and vice versa. Therefore it is essential to maintain the temperature within the limit.

V. Conclusion

During forging the completion of billet forged at 10 second before arrangement of new system, but now the forging time for one billet is 6 second so, here the forging time is reduced and production is increased. The percentage of error is 36 during the normal forging steps but now reduced into 4 after the implementation of our new system of temperature maintainer. So if the billet size is increased, the number of rejection is likely to be increased. The temperature of forging is maintained at 1000 -1200 so, the quality assurance is increased towards customer and also to increase the die life time. Future work of this paper is online monitoring of forged billet using acoustic emission for to know the number of rejection billets and to be controlled.

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