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INVESTIGATION OF VARIATIONS OF THE LOCK-POSITION DURING A FORGING OPERATION

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ABSTRACT
High production rates of automotive parts are achieved by the use of eccentric presses. While operating a forging press, the lock-position of the dies changes due to varying thermal conditions of the dies and the press components. The consequence is the production of scrap. By measuring the thickness of the forged parts and the temperature of the die and the press components, the impact of the changing temperature on the lock-position of the die was evaluated. In order to investigate this phenomena, different dies for raw parts with varying dimensions were used. The results were analyzed by comparing the changes of the lock-position with the thermal expansion of the dies.
Keywords: Eccentric Press, Process Control, Lock-Position

1. INTRODUCTION
The main goal for production processes is economical efficiency. One influence on this is the scrap rate. A major part of the production of scrap occurs due to changing process parameters. One reason for this are the varying temperature fields of the press components and the tool. While launching production or during process interruptions the components are heated up or cooled down due to heat transfer phenomena. The lock-position of dies in mechanically driven presses varies due to these temperature effects. A tool system to process raw parts with different masses was developed and built. A different amount of heat is transferred into the tool during each stroke due to the different raw part masses.

2. STATE OF THE ART
Dimensional deviations of forged parts lead to interruptions of the manufacturing process. In order to reduce the error rate, quality management systems provide appropriate procedures. Examples are Failure Mode and Effect Analysis (FMEA) or Design Review [1, 2].
CAD- or FEM-systems are used as pre-production tools to prevent systematic errors [3]. Other applicable tools are data base systems, which help preventing organization errors. Another approach to increase the process stability is the on-line documentation of die wear. During the forging process die wear can be measured in-process by scanning of the dies with eddy current sensors for example [4, 5]. Another method to measure die wear during the forging process is presented by BRUEGGEMANN. He uses neural networks to classify the forming force [6].
Control systems have been presented especially for path-bound forging presses which adjust the lock –position of the forming machine automatically. The input parameters of this control mechanism are mass and temperature of the raw part. A variation of these parameters leads to a modified deflection of the press. Due to this effect the thickness of the finished parts scatters. By measuring the position of the bottom dead center of the ram a slide adjustment was controlled [7, 8].
An approach for a control of the position of the bottom dead center is presented by DOEGE [9]. With different process parameters dimensionless parameters are calculated. These parameters are used to

define correlations to the quality parameters. Another principle to gain information of the process quality is to analyze parameter trends [10]. With this system short- and long term trends can be analyzed and counteracted without measuring the parts directly.
DOHMANN investigated an approach to reduce the start-up time of a forming process. Therefore the forming press and its periphery is sub-divided in components with individual process parameters and its input and target values. By application of a process control to this parameter the start-up time could be reduced significantly [11].

3. DIMENSIONAL CHANGES OF THE PRESS DUE TO ABSORBED HEAT

Metal forming machine tools mainly heat-up because of heat transfer from the hot work piece. Electrical energy is converted into heat by friction of the drives, the ram and the bearings, as well. A major part of energy is removed directly from the die by the evaporated cooling lubricant and by heat exchange of the press and its environment because of heat conduction, radiation and convection.
The temperature of cold dies increases because of the input of energy while launching production. Thus, the temperature difference to other press components like the ram or the press frame is rising. The amount of the transferred heat depends on the temperature gradient and the size of the contact surface of the components. The press components next to the dies are mostly larger and do not heat up as fast and do not reach a comparable temperature level since the larger surfaces of these components allow for a better heat exchange with the environment. After a certain amount of forged parts a steady-state temperature of the components is reached. The changing temperature of the dies and the press components lead to a variation of the geometrical dimensions.

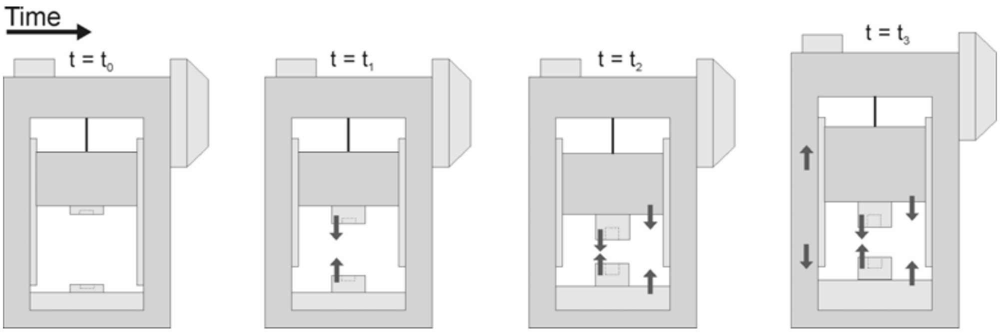

Figure 1. Thermal expansion of a mechanical press during launch of production

The chronology of the thermal expansion of the different components is depicted in Fig. 1. Starting with a cold press ($t = t_0$) the dies are the first components to expand. The distance between the tools will decrease accordingly because the press components remain cold ($t = t_1$). The next components which expand are the ram and the tool holder. Thus, the lock-position of the dies will decrease further ($t = t_2$). Following, the press frame is warming up as well. This effect counteracts the decrease of the lock-position ($t = t_3$).

4. EXPERIMENTAL SET-UP

The used tool system for the investigations is shown in Fig. 2. It is a tool for closed-die press forming with flash. In order to forge symmetrical parts, the upper tool is equal to the lower one. The forging tests were carried out with an automated eccentric press “Eumuco Maxima” with a maximum press force of 3.05 MN, which is shown in Fig. 3. Press force, ram displacement and the temperature of the press components (die holder, ram and press frame) and the dies are measured.
The cylindrical steel slugs are made from C45 and have a mass ratio of two and four compared to the smallest part with a mass of 0.12 kg. The used dies differ only in the geometry of the engraving in order to forge geometrically similar parts. The cooling condition of the tools was kept constant for all investigations. Thus, the same amount of energy is transmitted from the dies to the environment during each cycle. The deviations of the lock-position were measured indirectly by measuring the thickness of the flange of the forged parts. In order to prevent errors due to die wear the measuring points are placed in areas with very few wear.

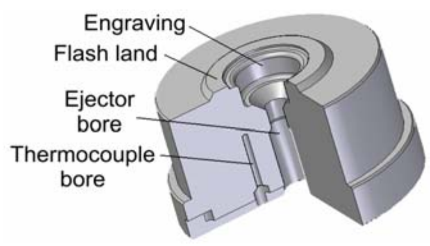

Figure 2. Tool geometry

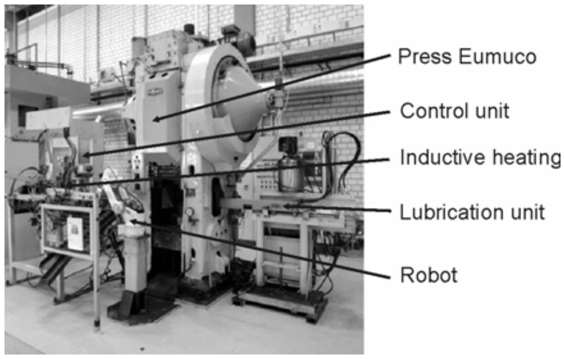

Figure 3. Automated press Eumuco Maxima

5. EVALUATION OF THE RESULTS

In Fig. 5 the temperature development of the components for the medium-size raw part is given. The temperature of the tools are increasing from the beginning of production. The lower and upper tool reach its steady state temperature after 600 and 300 forged parts, respectively. The press components heat-up very slowly and the gained temperature difference from room- to steady-state temperature remains small compared to the tools. The development of the tool temperature shows significant dropping of the temperature after 70, 400, 650 and 1400 forged parts due to process interruptions of up to 60 s. Shortly after resuming production, the previous temperature level is reached and the temperature of the tools increases until the steady-state temperature of the tools is reached. The temperature of the press components is not influenced significantly by theses interruptions. During the 1400 forging cycles the press components did not reach its steady-state temperature.

The development of the deviations of the lock-position are depicted as well. The deviation for this part dimension has a maximum value of 0.2 mm compared to the lock-position of the dies of the first stroke. After 600 cycles a constant level is reached and the deviation remains constant with small discrepancies. The discrepancies after 400 and 1400 cycles occur parallel to the process interruptions and the according decrease of the die temperature. The lowest value of the deviations is measured during a constant level of the tool temperature for 1000 cycles when both dies have reached its steady-state-temperature although the press components still heat up slowly.

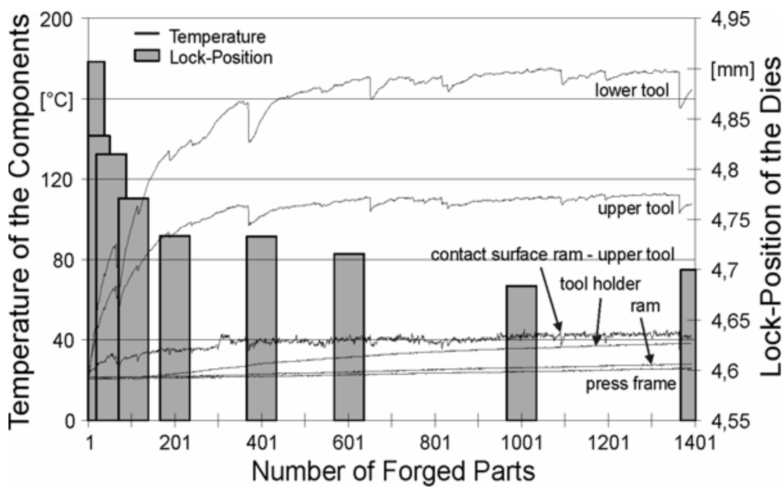

Figure 5. Component temperature and deviation of the lock-position for the medium mass

Because of the correlation between the development of the tool temperature and the deviation of the lock-position of the dies can be assumed, that the thermal expansion of the dies has an impact on the deviations of the lock-position. In Fig. 6 the measured deviations are compared to the thermal expansion of the tools. The thermal expansions were calculated from the tool temperature of the lower- and upper tool, the height of the tool system and the thermal expansion coefficient of the used steel. It can be observed, that the calculated deviations fit the measured values very well for the different raw part dimensions.

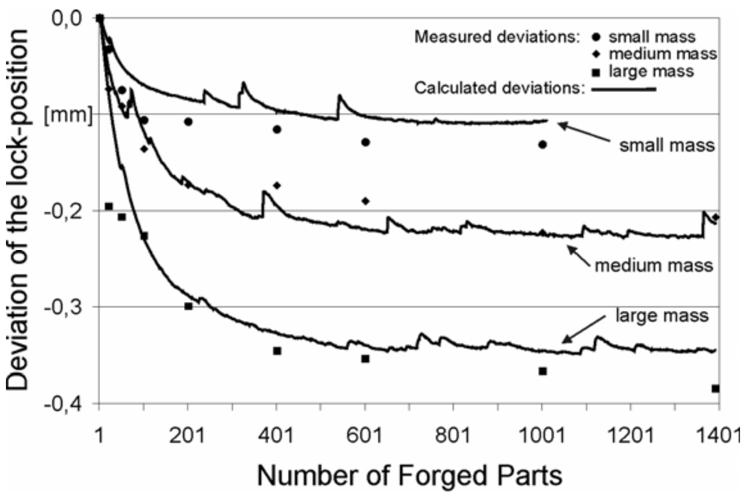

Figure 6. Comparison of the measured and calculated deviations of the lock-position for different raw part masses

Because of the different surface of the dies for the different parts, a higher amount of heat flows into the tools during the pressure dwell time. Thus, the thermal expansion of the press components and the dies is increasing as well.

With these results a control mechanism for a slide adjustment by measuring the base temperature of the tools is possible. Thereby the lock-position can be adjusted contrarily to the thermal expansion of the dies and counteract thermal influences during launch of production or process interruptions.

6. CONCLUSION

Eccentric presses are subject for investigations of lock-position deviations during the start-up phase or process interruptions. These deviations occur due to the changing temperature of the press components and the dies since heat is transferred from the hot parts into the metal forming machine tool. The thermal expansion of the dies has major impact to the deviations of the lock-position, since the deviations were constant from the time when the tools reached its steady-state temperature. The deviations of the lock-position of the dies were compared with the calculated thermal expansion of the dies which leads to a good correlation.

7. ACKNOWLEDGEMENT

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8. REFERENCES

[1] Pfeifer T., Dahmen J., Gaida W. (1998) Qualitätsmanagement in der Produktionstechnik – Handlungsschwerpunkte und Perspektiven. Werkstattstechnik Vol. 88.

[2] Masing W. (1994) Handbuch für Qualitätsmanagement. 3. Auflage, Hanser Verlag, München.

[3] Doege E. (1996) Entwicklung eines wissensbasierten Systems zur numerischen Identifikation von Schmiedeparametern. Arbeitsbericht, Hannover.

[4] Doege E., Brüggemann K., Dohmann J. (1996) Methods for the Forging Process to improve Productivity and Quality. Proceedings of the Sixth International FAIM Conference, Manufacturing Research Center Georgia, Institute of Technology, Atlanta, Georgia.

[5] Doege E., Dohmann J., Brüggemann K. (1996) New Methods for Quality Assurance in Hot-Die Forging. 4th International Conference on Automation Technology, Mechanical Industry Research Laboratories/ITRI, Hsinchu, Taiwan; R.O.C.

[6] Brüggemann K. (1997) Methoden des Qualitätsmanagement beim Gesenkschmieden. Fortschritt-Berichte VDI, Reihe 2, Nr. 432, VDI Verlag, Düsseldorf.

[7] Wegener W. (1989) Rechnergestützte Nachführung der Werkzeugschließlage zur Erhöhung der Arbeitsgenauigkeit von Schmiedepressen. Fortschritt-Berichte VDI, Reihe 2, Nr. 172, VDI Verlag, Düsseldorf.

[8] Berglar-Bartsch, K. (1991) Praxisgerechte Lösungen für die Schmiede der Zukunft. IDS Maschinenkolloquium, Hagen.

[9] Doege E., Huxholl L. (1995) Using characteristic values to represent relevant metal forming parameters. Annals of the WGP, Volume II/2.

[10] Schneider H. (2002) Erkennung und Korrektur trendartiger Qualitätsveränderungen beim Präzisionsschmieden. Fortschritt-Berichte VDI, Reihe 2, Nr. 599, VDI Verlag, Düsseldorf.

[11] Dohmann J. (2000) Reduzierung instationärer Betriebszustände beim Gesenkschmieden. Fortschritt-Berichte VDI, Reihe 2, Nr. 533, VDI Verlag, Düsseldorf.