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*Make Harmony between Technology and Nature, and Your Mind will Fly Free as a Bird*
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# OPTIMIZATION AND VERIFICATION OF WARM FORGING TEMPERATURE OF STEEL

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***Abstract:*** *Warm forming process is very interesting for technology practice due to its low consumption of energy, better surface quality, better forming precision and time saving. The right selection of warm forming temperature is very important. This contribution provides information about mechanical properties of plasticity and workability of structural steel in dependence on warm forming temperatures. The warm forming temperature was optimized from the results. Temperature selection was verified by the numeric simulation of closed die warm forging process using the finite element method.*
***Key words:*** *plasticity, workability, warm forging, numeric simulation*

## 1. INTRODUCTION

Warm forming process is a compromise between cold forming and hot forming processes. The process passes at temperatures which are over recovery temperatures but below down hot forging temperatures. At these temperatures forming process has better formability than cold forming and in comparison with hot forming it has better forming precision (Lee & Jou, 2003).

Temperature is an important argument for testing of metals in agreed conditions (Kapustova & Polak, 2005). Plastic deformation is made during cold forming of metals by slip and material is strain hardened. Warm forming passes with partial strain hardening of metal above recovery temperature and below temperature of recrystallization (Forejt & Piska, 2006). Microscopic and macroscopic stresses are removed by recovery and physical and partly plastic properties of metal improve. Values of tensile strength and yield point decrease and formability increases. In this interval of temperatures, thermally activated dislocations movement passes and their density lowers due to annihilation. Plastic properties of metals are not a linear function of temperature. For forming of structural steels a range of temperatures from 600°C to 800°C is recommended (Novotny, 2000). Therefore for production practice is necessary the investigation of optimal warm forming temperatures (Pernis, 2007), because the temperature range has a relatively narrow band and is bounded by the zone of steels brittleness.

## 2. EXPERIMENT

Subject of workability research at increased temperatures are structural steels STN 411373 (EN 10025A1 1.0036) and STN 414220 (EN 10084 1.7131). These steels are standard material for bulk cold and hot forming. They are widely used for production of dynamic stressed machine components in the machine industry.

Suitability of examined steels for warm bulk forming was weight by tensile test at higher temperatures (according to standard STN EN 10002-5). Cylindrical bar tensile test specimens were used. The gage length was 80mm, diameter 8mm. The specimens were tested at temperatures 600, 650, 700, 750, 800 $^{o}$C - warm forming temperatures of steels. At each temperature three specimens were tested.

## 3. EXPERIMENTAL RESULTS

From stress strain diagrams and dimensions of specimens strength limit $R_m$, characteristics of plasticity for warm workability (percentage reduction of area Z, index of plasticity to rupture according to Kolmogorov $\lambda_R$) and Paur's index of forming capacity $D_{sm}$ were calculated. The index of plasticity according to Kolmogorov $\lambda_R$ was calculated according equation (1), where $d_0$ is an original diameter of test specimen, $d_u$ is an diameter of specimen in failure place, Paur's index of forming capacity $D_{sm}$ was calculated according the equation (2), where Z is reduction of cross sectional area.

$$\lambda_R = 2\sqrt{3}\ln\frac{d_0}{d_u} \tag{1}$$

$$D_{sm} = \frac{1}{1-Z} - 1 \tag{2}$$

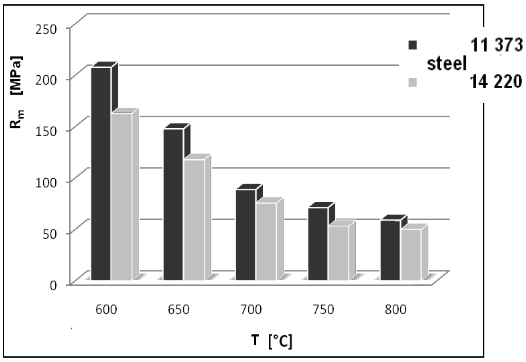


Fig. 1. Temperature course of tensile strength

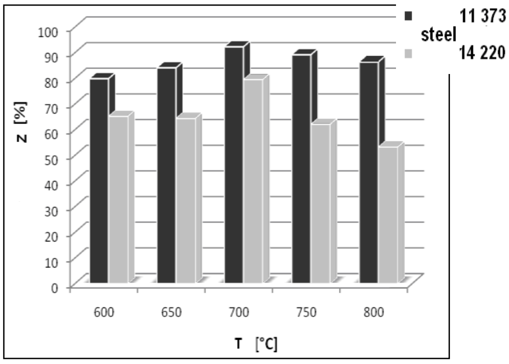


Fig. 2. Temperature course of percentage reduction

Temperature course of tensile strength is in Fig. 1, temperature course of percentage reduction of area is in Fig.2, temperature course of index of plasticity is in Fig. 3, Paur's index of forming capacity $D_{sm}$ is in Fig. 3.

Based on the results it is obvious that with increasing temperature tensile strength decreased. On the other hand the value of percentage reduction of area increased. From temperature course of percentage reduction in Fig. 2 results, that both two steels have the greatest value of percentage reduction at 700°C. At this temperature the greatest increasing of plasticity showed also the index of plasticity to rupture $\lambda_R$ and the index of forming capacity $D_{sm}$, as it is shown in Fig. 3 and Fig.4.

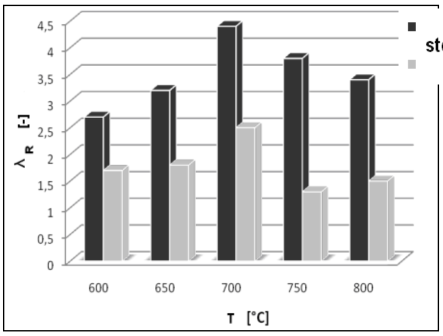


Fig. 3. Temperature course of index of plasticity to rupture

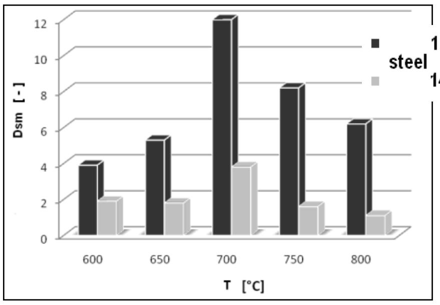


Fig. 4. Temperature course of index of forming capacity

## 4. NUMERIC SIMULATION

Warm forming leads to better forming precision and surface quality, but the forming process requires greater forming forces and stress of forming tools in comparison with hot forming. To obtain an influence of some factors to loading of a toll using the standard solving method is impossible and using an experimental method very expensive and time consumption. Simulation software enables monitoring of these processes before expensive toolmaking and optimizes parameters of process at specific conditions too (Spisak, 2000).

From the experimental results, (see chap. 3) optimal warm forging temperature of structural steels 700°C was recommended. An example of numeric simulation of plastic flow at temperature 700 °C was applied to forging of drop forging in a closed die. A simulation software MSC SuperForge was used. Defined input conditions for the simulation of forging process of drop forging with a ring shape in the simulation Programme MSC SuperForge: Crank press LZK 1000 - friction 0.1, die temperature 150˚ C; work piece – cylinder Ø48x97 mm, steel STN 414220 (EN 10084 1.7131), temperature 700°C. Results of forging process simulation of 14220 steel are in Fig. 5 (corresponding values marked by dots).

## 5. DISCUSSION

Tensile strength decreased and on the other hand value of percentage reduction of area increased with increasing temperature. The best plastic properties of structural steels are at 700°C. On the basis of the experimental results 700°C was selected as an optimal warm forging temperature. The numeric simulation of forging process at warm temperature 700°C showed very good material flow. Stress, contact pressure and forging force are relatively high, but in case of applying this technology to small and medium drop forgings the forces and stresses have acceptable value.

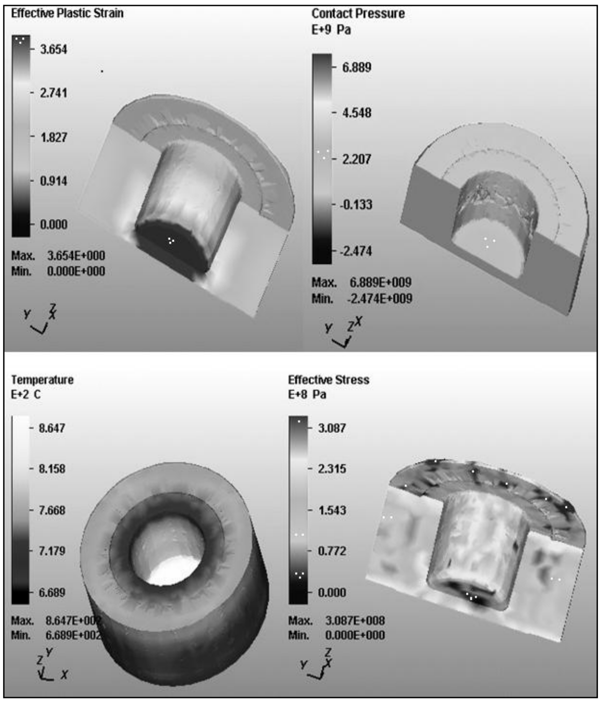


Fig. 5. Results of forging process simulation

## 6. CONCLUSION

Based on mentioned results it is possible to apply the technology of warm forging to small and medium drop forgings (with mass from about 0,5 to 5 kg) with simple and not rugged shapes. Closed die warm forging process can lead to production costs savings - reduction of energy and time consumption and in conjunction with flash loss forging reduction of material consumption too.

## 7. REFERENCES


Forejt, M. & Piska, M. (2006). *Theory of machining, forming and tools,* CERM, ISBN 80-214-2374-9, Brno

Kapustova, M. & Polak, K. (2005). The importance of temperature influence research on the plasticity of steel for further development of warm forming technology. *Manufacturing Engineering*, Vol. 5, No. 1 (2009), pp. 25 – 27, ISSN 1335-7972

Lee, R. S. & Jou, J. L. (2003) Application of numerical software for wear analysis of warm forging die. *Journal of material processing technology*, Vol. 140 (2003), pp. 43 - 48, ISSN 0924-0136

Novotny, K. (2000). Possibilities of warm forming application, *Proceedings of 5th International Conference FORM 2000*, September 19 – 20, Brno, ISBN 80-214-1661-0, pp. 211-213, TU Brno, Brno

Pernis, R. (2007). *Theory of metal forming,* TnUAD, ISBN 978-80-8075-244-6, Trencin

Spisak, E. (2000). *Mathematic modelling and simulation of technological processes*, Typo Press, ISBN 80-7099-530-0, Kosice