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TMMOB METALURJİ ve MALZEME MÜHENDİSLERİ ODASI

BM'S-P02
Microstructure and Mechanical Properties of Si_3N_4 Based Biocomposites

Dilan Bozkurt, Melis Kaplan, İpek Akın, Gültekin Göller
İstanbul Technical University
Türkiye

BM'S-P03
Manufacturing of Metal Based Dental Brackets

Özge Yalman[1], Ahmet Topuz[2]
[1]Koç University, [2]Arel University
Türkiye

BM'S-P06
Characterization of Peo-Deposited TiO_2/HA Nanocomposite Coatings

Fatma Songur, E. Arslan, B. Dikici
Atatürk University
Türkiye

BM'S-P07
Production of Luffa Cylindrica Reinforced Silk Fibroin/Chitosan Hydrogel Scaffolds for Cartilage Tissue Defects

İbrahim Erkut Özer, Aylin Ziylan Albayrak,
Oylum Çolpankan Güneş, Gizem Baysan, Hasan Havıtçıoğlu
Dokuz Eylül University
Türkiye

BM'S-P08
M-V-O (M=Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn) Type Compounds: Microwave Syntheses and Structural Characterization

Gülşah Çelikgül
Balıkesir University
Türkiye

BM'S-P09
Direct Focused Ion Litography of Biphasic Calcium Phosphate (BCP) Bioceramics Surfaces

Feray Bakan, Melike Çokol Çakmak, Meltem Sezen, Elif Çelik, Zaeema Khan
Sabancı University
Türkiye

Steelmaking Technologies and Applications Symposium
Çelik Üretim Teknolojileri ve Uygulamaları Sempozyumu

STA'S-P01
Failure Analysis of Hot Forging Dies

Nuray Beköz Üllen
İstanbul University-Cerrahpaşa
Türkiye

STA'S-P02
Investigating the Effect of Compaction Temperature on Dry Sliding Wear Behavior of Austempered High Carbon Powder Metal Steel

Onur Altuntaş, Ahmet Güral
Gazi University
Türkiye

Failure Analysis of Hot Forging Dies

Nuray Beköz Üllen

Istanbul University, Department of Metallurgical and Materials Engineering, Istanbul, Turkey

Abstract

Hot forging process is a conventional method used for metal forming to meet the demands for lower production costs and shorter times. Forging die is an important part for the hot forging industry. Hot forging dies are exposed to wear and fatigue owing to being continuously under thermal effects and cyclic mechanical loads. Failures of these components leads to serious problems in terms of expected service life of the die and therefore manufacturing cost of the product. Most of the hot forging dies failures are caused due to inadequacy of die materials, die design, die manufacturing or forging operations. Insufficient forging ratio, insufficient cleanliness and heat treatment of the dies, small corner radius, shortage of the die width and thickness, inadequate surface treatment, weld reparation of the die surface, insufficient pre-heating, inadequate die face and lubrication are the major factors that lead to failure of the hot forging dies that are used in the metal forming process. In this study, main types of damages on industrial upper and lower hot forging dies for the hot forging operations and reasons of these mentioned above failures were investigated and evaluated by visually inspecting several different samples. Solutions were also suggested for the each hot forging die failure case.

1. Introduction

Hot forging is one of the most conventional metal-forming processes used in the production of critical parts in the manufacturing of automobiles and industrial machine components [1]. Die service life widely influences manufacturing costs, productivity and product quality. Die service life is dramatically shortened by thermal cycle, excessive metal flow and a decrease in die hardness during hot forging process [2]. Generally, the occurrence of various types of damage and their progress are additionally influenced by steel material used for the die and applied technological processing parameters, die shape design, i.e. planning of forging sequences, die manufacturing, forging parameters, applied forging presses, as well as forging stock properties, e.g. formation of oxide scale, local bonding between the die sand the workpiece, etc. Also, the steel for the die should be produced in an appropriate way, i.e. at optimal process parameters, in order to achieve optimal microstructure, optimal grain size and distribution, type, size and shape of carbides. Finally, the manufacturing process of the die should be carried out without negative impacts on die surface quality. The die shapes should be optimized through adequate sequential forging steps in order to avoid areas where loads are essentially higher than in other die areas [3-4]. Forging industries have shown great interest in improving tooling used in hot forging processes due to new requirements on high productivity and reducing cost in forging processes. Even small improvements in this field bring a large economic benefit to the companies [5]. Hot forging die failures for parts used in different sectors are caused by inadequacy of variables such as die materials, die design, die manufacturing and forging operations. In order to prevent die failure and to improve die life many efforts have been made so far. The most of hot forging die failures are caused by inadequacy of influencing variables such as die materials, design, manufacturing and forging operations. The influencing variables and causes of hot forging die failures can be classified as shown in Table 1[4].

Table 1. Influencing variables and causes of hot forging die failures. [4]

Influencing variables	Cause of failure
Die materials	Insufficient forging ratio Nonmetallic inclusions Insufficient cleanliness Inadequate heat treatment
Die design	Small corner radius Insufficient impression shape Shortage of die width and thickness Insufficient performing shape
Die manufacturing	Insufficient finishing Inadequate surface treatment Electro sparked irregular surface Weld repair
Forging operations	Insufficient pre-heating Inadequate die face Insufficient heating of ingot Inadequate lubrication

In this study, main types of damages on industrial hot forging dies for the hot forging operations and reasons of these mentioned above failures were briefly summarized by visually inspecting. Influencing variables and the cause of die failures for forged parts are classified. Also; the industrial problem and the recommended modifications of the process parameter are presented.

2. Experimental Procedure

2.1. Failure analysis process

Failure analysis process for failed hot forging die is really same as that of conventional machine parts [6]. The examination process mentioned in many studies is as shown in Figure 1 [4]. Of course failure analysis of hot forging die failure must be conducted for each failed hot forging die. Firstly, macroscopic observations are made for failed hot forging die; as in this study. Examinations on influencing factors variables on hot forging die failure are conducted for forging equipment, die manufacturing process and forging die steel, respectively. If necessary, detailed failure analysis and simulation tests are performed. Microscopic observation is conducted in the process of detailed analysis. The necessary preventions are taken after the cause of the fault has been tested.

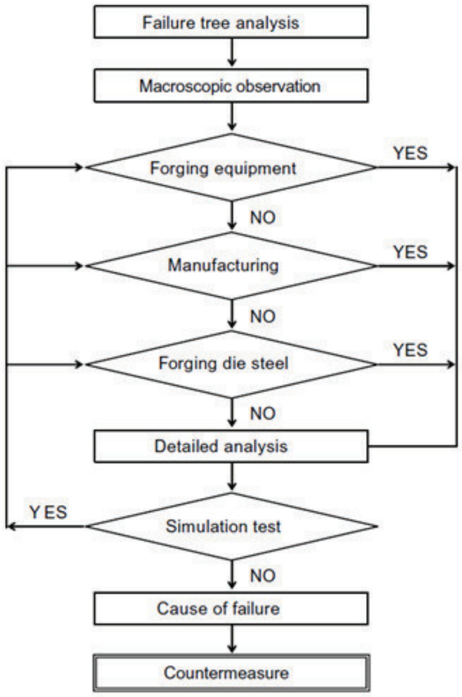


Figure 1. Failure analysis process for forging die [4].

2.2. Forging dies

A high performance Cr-Mo-V alloyed hot work tool steel was used as the die material. The X38CrMoV5 steel is widely used for forging dies. This die steel is characterized by excellent toughness, ductility in all directions, good tempering resistance and high-temperature strength, excellent hardenability and good dimensional stability during heat treatment as well as during the coating process [7]. The forging process consisted of three stages: Blocker, preform and finishing stages. There were 2 dies for each stage; 1 upper and 1 lower. Each of the forging dies was cut using a sewing machine from a round 420 mm diameter rod. The dies were machined using CNC turning.

2.3. Die lubricant

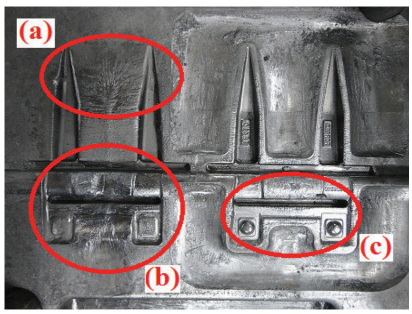
To reduce the adverse effects created by friction in forging process; a lubricant composed of processed micro-graphite and patented materials with 1.2 kg/l density and 45% solid content was used. The lubricant was mixed with pure water in the ratio of 1/8 as recommended by the manufacturer.

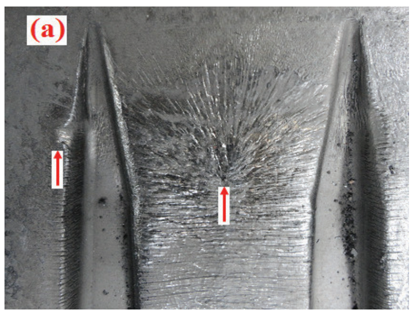
2.4. Forging procedure

A forging billet made of Mn-Cr steel is cut to the length of 110 mm in a 650 tones cold shearing machine. For the dies used in this study; the billet was then heated to a temperature of 1150 °C in an induction heater and was transferred to the 2650 metric tons forging press.

3. Results and Discussion

Careful macroscopic examination of the whole die surface was performed and the reasonable reasons of the failure determined. Photographs of the different hot forging dies examined are given in Figures 2-6. Figures 2 and 3 show the dies of BSC wide and BSC narrow guard fingers which are used as protective sheath in cutting edges of agricultural machines, respectively. Both dies had a similar design of cavities. Figures 4-6 show the hot forging dies for connecting rod different types. Figure 2 (a), (b) and (c) shows a plastic deformation, wear and typical heat cracks observed on forging die, respectively. Wear and plastic deformation observed on hot forging die are clearly shown in Figure 3 (a) and (b). Cracks caused by thermal fatigue is shown in Figure 4. Spalling and surface cracks around its shown in Figure 5. These surface cracks causes of insufficient quality of forging products. Mechanical damage caused by die wear is shown in Figure 6.





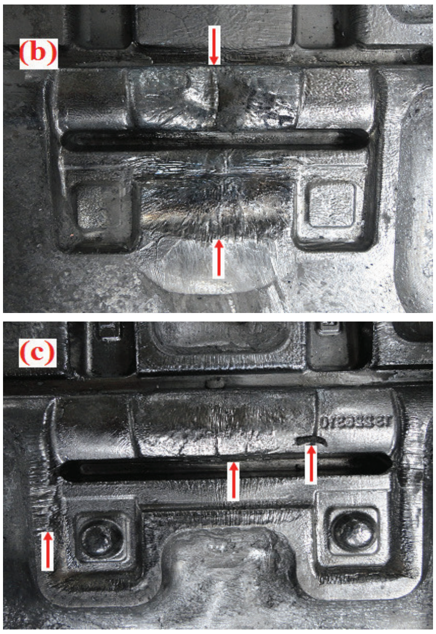


Figure 2. Hot forging die failure of guard fingers.

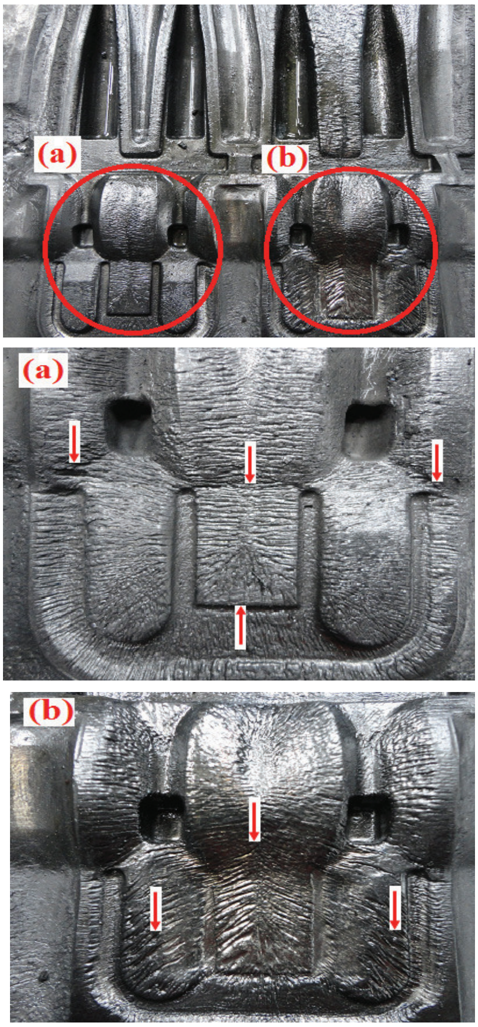


Figure 3. Hot forging die failure of guard fingers.

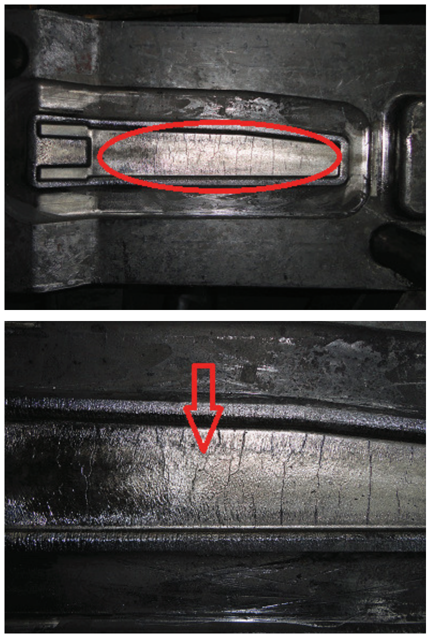


Figure 4. Hot forging die failure of connecting rod.

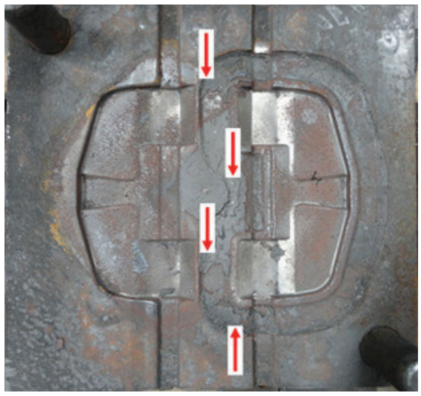


Figure 5. Hot forging die failure of connecting rod.

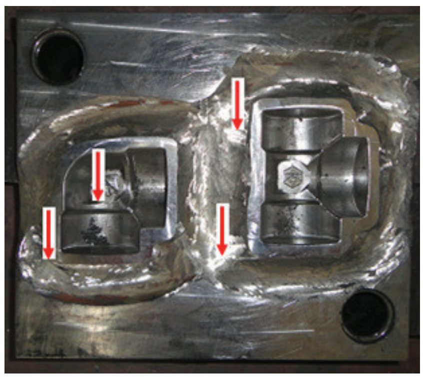


Figure 6. Hot forging die failure of connecting rod.

In hot forging processes, the factors affecting die life are thermal fatigue, plastic deformation and wear. Among these, wear is the main failure cause in hot forging dies. Cser et al. [8] reported that die life in forging process is affected by wear in over 70%. The lifetime of hot forging dies is often shortened by surface cracking and subsequent material splitting. Most of the hot forging die failure initiated from impression corner. Therefore determination of the figure and its dimensions of impression corner is very important in die design. In order to prevent hot forging die failure figure and dimensions of impression corner must be determined very carefully [9].

4. Conclusion

In this study influencing variables and causes of hot forging die failures and characteristics of die failures are briefly summarized.

- The hot forging die failure is complicated with various kind of influencing variables such as die material, die design, die manufacturing and forging operations.
- Die failure may be attributed to one of the following factors [10]: tool steel selection and quality; die design and manufacturing; heat and surface treatments; forging process parameters. Die failures observed in this study were determined as wear, thermal and mechanical fatigue, and plastic deformation, spalling and cracks observed on a hot forging die
- Three mechanisms of wear were detected on die surfaces, i.e. thermal fatigue, mechanical fatigue and abrasion [11]. Wear resistance is important properties of hot forging die steel. Careful control through melting to heat treatment of hot forging die steel prevent hot forging die failure.
- In order to improve the life time of hot-forging dies, it is first of all necessary to improve the design of dies in preceding forging sequences with the goal to reduce deflection of die cavities in the ultimate forging sequence.

Acknowledgment

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References

[1] D.H. Kim, H.C. Lee, B.M. Kim and K.H. Kim, Journal of Materials Processing Technology, 166 (2005) 372-380.
[2] A. Caporalli, L. Antonio Gileno and S. Tonini Button, Journal of Materials Processing Technology 80-81 (1998) 131-135.
[3] B.A, Behrens, F.Schaefer, Journal of Materials Processing Technology, 167 (2005) 309-315.
[4] R. Ebara, K. Kubota, Engineering Failure Analysis, 15 (2008) 881-893.
[5] M. Bayramoglu, H. Polat and N. Gerena, Journal of Materials Processing Technology, 205 (2008) 394-403.
[6] R. Ebara, K. Kubota, J. Jpn. Soc. Technol. Plast., 23 (1982) 977-983.
[7] ASM Handbook, ninth ed., Forming and Forging, ASM 14, 1988.
[8] L. Cser, M. Geiger and K. Lange, Proc. Inst. Mech. Eng., 207 (1993) 223-239.
[9] O. Brucelle, G. Bernhart, Journal of Materials Processing Technology, 87 (1999) 237–246.
[10] V. Garat, G. Bernhart and L. Hervy, Journal of Materials Processing Technology, 147 (2004) 359-369.
[11] S. Abachi, M. Akkök and M.İ. Gökler, Tribology International, 43 (2010) 467-473.