ANNALS OF FACULTY ENGINEERING HUNEDOARA
– International Journal of Engineering
Tome XI (Year 2013) – FASCICULE 2 (ISSN 1584 – 2665)

1. Miroslav PLANCAK, 2. Dragisa VILOTIC, 3. Ognjan LUZANIN, 4. Igor KACMARCIK,
5. Aljosa IVANISEVIC, 6. Dejan MOVRIN, 7. Plavka SKAKUN, 8. Mladomir MILUTINOVIC

A REVIEW OF THE POSSIBILITIES TO FABRICATE CONNECTING RODS

1-8. UNIVERSITY OF NOVI SAD, FACULTY OF TECHNICAL SCIENCE, TRG DOSITEJA OBRADOVICA 6, NOVI SAD, SERBIA

ABSTRACT: Connecting rod (conrod) is one of the main components in every internal combustion engines. It is subjected to high tensile, compression and bending loads. It is possible to manufacture connecting rods by different technologies and from different materials. Which technology and material will be applied depends on application case (e.g. high performance automobile or compressor of low performance), batch size etc. Most frequently applied methods for conrod production are hot forging, PM forging and casting. Each of these technologies has its advantages and drawbacks. This paper illustrates different possibilities to manufacture connecting rods. Furthermore, comparison of presented methods has been elaborated.
KEYWORDS: Connecting rods, forging, casting, powder metal based processes

INTRODUCTION

In every combustion piston engine (car, motorcycle, trucks, compressor and other type of vehicle with the internal combustion engines) one of the main components is connecting rod ("conrod"). It connects the piston with the crankshaft, converting linear to rotational motion (Fig 1.). Connecting rod is highly stressed component, as it is subjected to the cyclic dynamical tensile and compressive loads. It is produced mainly from ferrous materials (steel), but in some cases where lightweight of the construction is essential (such as motor-sport) titanium or aluminum alloys can also be applied.

Conrod is a mass product. Considering the fact that estimated production of 5 cylinder automobiles in 2010 was around 70 million worldwide, this means production of 350 million conrods in that year for cars only. Beside automobile, a number of other applications (vehicles, compressors...) are manufactured in which conrod is a vital component. As reported in [1] only in China annual requirement for conrods is over 70 million.

Figure 1.Connection rod converts linear motion of the piston to rotary motion of the crankshaft

Project, design and fabrication of connecting rods has been a subject of number of papers. In [2] authors elaborate advanced manufacturing systems for forging products. They have concentrated on the precision forging and its modified requirements on the process design and production control. Analysis of hot die forging process by FE has been presented in [3]. In this work a new classification of the axis-symmetrical forged parts has been proposed. Paper was focused on the forging products from the group 1 from this classification as they are spread in the metalworking industry. Description of closed die technologies for hot forging is given in [4]. Main requirements for closed die forging are specified, such as process sequences, tools and press. Forging steps for production of connection rods are briefly shown. Forging of connecting rods in the Chines industry is illustrated in [1]. As annual output of automobiles in recent years in China is rapidly rising (in 2003 year total output in China was 4.443.700 cars which is the fourth rank in the world), production of vital part of every automobile - connecting rod - is of upper importance. About 200 companies in China forge connecting rods. Paper also describes the main achievements in precision forging in China with focus on quality of forged products. Having in mind that conrod is a mass-product, choice of optimal way to manufacture these components is of vital techno-economical importance.

© copyright FACULTY of ENGINEERING - HUNEDOARA, ROMANIA

There are different possibilities to fabricate connecting rods:

- *hot forging*
- *casting*
- *powder metal (PM) based processes*

Every of these technologies requires additional machining operations such as grinding the side faces, drilling of holes etc.

Current paper presents, analyses and compares main technologies to produce connecting rods. Advantages and drawbacks of above mentioned technologies are highlighted.

POSSIBILITIES TO MANUFACTURE CONNECTING RODS

***HOT FORGING** is a predominant technology to fabricate conrods. Due to a complex geometry, conrod cannot be produced in one blow and therefore dies with several impressions have to be employed. Basically, conrod forging can be executed in one-at-a-time and two-at-a-time version. One multi step one-at-a-time forging variant which is often applied in industry is shown in Figure 2. Before forging, billet is heated to required temperature and then transported to the die.*

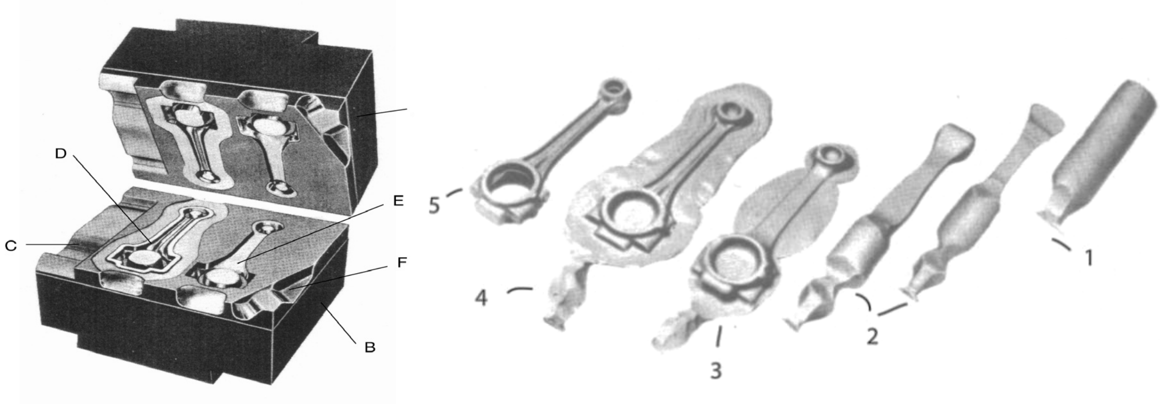

Figure 2. One-at-a-time conrod forging ***Error! Reference source not found.***

Forging die consists of fullering, edging, blocking and finishing impressions. As it is seen, most intensive material flow takes place in blocking impression (D) and minimum flow occurs in finishing impression (E). After forging, trimming in a separate die is performed. Process steps are given in Figure 3.

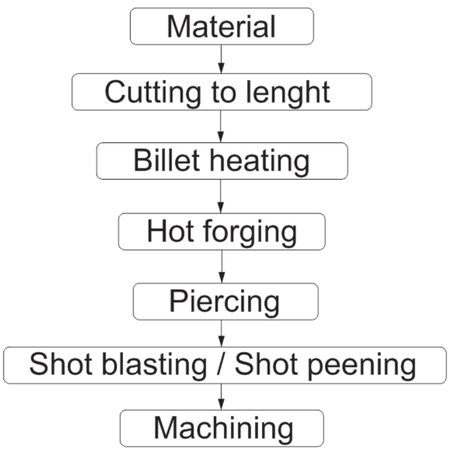

Figure 3. Process steps for hot forging processes

In some cases preforming operations for conrod forging, which serve to distribute the material before actual forging, can be carried out also by reduced rolling and cross rolling operations [1].

In order to improve forging productivity two-at-a-time forging version are also developed. Forging steps for two versions of such a technology are presented in Figure 4. As it is seen, in the first case cap parts have to be forged separately.

a)

b)

Figure 4. Two-at-a-time conrod forging ***Error! Reference source not found.***

Smaller size conrods are preferably forged in a two-at-a-time version while larger conrods in one-at-a-time version. After forging, conrod is subjected to the heat treatment and, in some cases, to straightening.

Increased geometrical accuracy and quality of forged conrod can be achieved by precision forging [2]. In this type of forging no flash is formed. Dies for precision forging have a draft angle 0° and tolerances are narrower than it is the case in conventional forging. Volume of starting billet has to be precise as if it is undersized, die is not completely filled and in case that billet volume is oversized die damage is likely to occur.

Casting. *Cast conrods are produced in green sand molds. Due to specific requirements of casting technology design of conrod has to be modified (I-beam cross section, radii). Material utilization in conrod casting reaches 90%. Mechanical properties of cast conrod are improved by sand blasting or shot peening.*

Powder metal (PM) based process. *In this process pre-blended powder material is filled up into the die, and then compacted at room temperature with the subsequent creation of preform by sintering at 1050-1300°C for 15 minutes. This preform is afterwards ejected from the die, heated in the furnace and finally hot forged to the final shape. In this way high density forging is produced.*

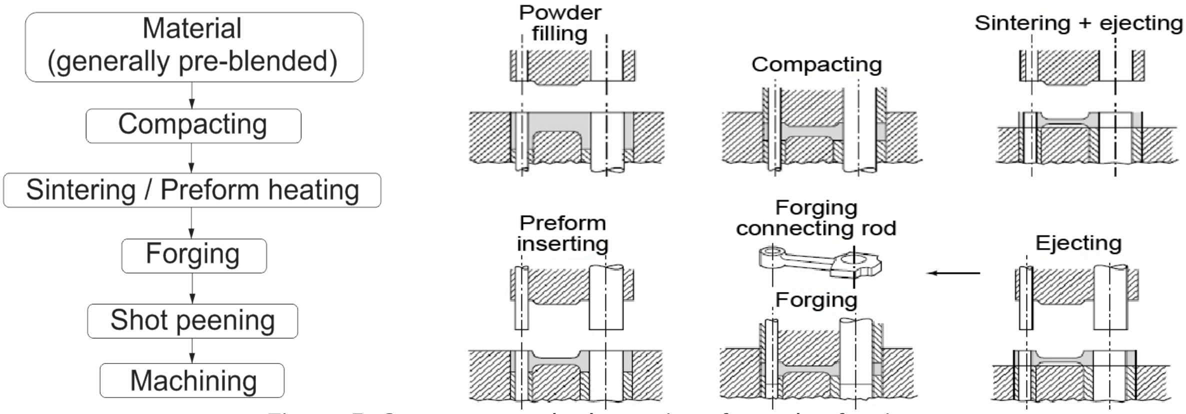

Figure 5. Sequences and schematics of powder forging

In figure 4 these main steps of this alternative are given:

1 - powder filling
2 - compacting
3 - ejecting the preform
4 - sintering
5 - inserting the sintered rod into the forging die
6 - forgedconrod
7 - ejecting final forging

After ejection, conrod is cooled to room temperature in a protective atmosphere. Following operation is shot peening in order to remove forging pole and to increase strength of the conrod.

First application of conrodpowder forgedwas realized at Porsche in 1970.

COMPARISON BETWEEN DIFFERENT TECHNOLOGIES

Comparison between different technologies of conrod productioncan be done by various criteria: mechanical properties, weight, cost competitiveness etc.

For high performance engines forged conrods are used. According to [1] 90% of all conrods produced in Chine are forged. Others 10% are powder forged or castings. Forged conrods possess high mechanical properties and are able to withstand high loads and are therefore applied in all cars where high velocity is required. Different types of steel alloys can be employed for conrod forging e.g. 4340 steel of chrome and nickel alloy.

Powder forged conrods are characterised by superior weight/tolerancecontrol, low subsequent machining costs, minimum material waste, dimensional consistency and accuracy. However, this alternative is up to 30% more expensive than forged conrods.This is due to high price of the starting materials and tooling.

Cast conrods possess excellent machinability. Besides that, it is economically competitive. However, somewhat poorer mechanical properties make it applicable only for lower horsepower engines.

In case of forging, not only steel but also other materials can be used. Aluminium alloys in combination with some matrix composites can be applied to reduce weight of the conrod and to enable faster acceleration of the engine. But, aluminium conrods are not durable enough and they must be changed more frequently.

For racing engines (Formula 1) titanium conrods have been used. They are characterized by very high strength to mass ratio. However, due to high cost of titanium this alternative is very limited.

Within one of the Daimler-Benz program hybrid connecting rod have been investigated. These conrods consist of carbon fibber reinforced by plastic shank section with titanium ends [6], [7]. Main advantage of such conrod is low weight. This solution is still at the level of laboratory investigation.

CONCLUSIONS

Demand of industry for components produced with high techno-economical performances is permanently growing. Such trends are exceedingly noticeable in automotive industry.

One of the main components in every automobile is connecting rod. It converts linear motion of the piston into the rotating motion of the crankshaft and it is highly stressed by cyclic pushing and pulling loads.

Due to its central role in every combustion piston engine, mechanical reliability of every conrod is of upmost importance. Conrod mechanical properties depend on used material and applied manufacturing technology. Current paper elaborates three most frequently employed manufacturing processes to fabricate conrods: classical forging, casting and powder forging. Hot forging is still the most used technology, especially for high performance engines as it enables production of mechanically high reliable conrods. Powder forging alternative is somewhat more costly than classical forging, but it requires reduced additional machining operations and therefore has a strong growing market.

Cast connecting rods are used in the machines with lower performances (speed, load).

REFERENCES

[1] Wang Q., He F.: A review of developments in the forging of connection rods in China, Journal of Materials Processing Technology 151, pp. 192-195, 2004.

[2] Reinsch Steffen, Muessig Bernd, Schmidt Bernd, Tracht Kirsten: Advanced manufacturing system for forging products, Journal of Materials Processing Technology 183, pp. 16-21, 2003.

[3] Tomov B.I., Gagov V.I., Radev R.H.: Numerical simulations of hot die forging processes using finite element method, Journal of Materials Processing Technology 153-154, pp. 352-358, 2004.

[4] Doege E., Bohnsack R.: Closed die technologies for hot forging, Journal of Materials Processing Technology 98, pp. 165-170, 2000.

[5] Spur,G., Stöterle, Th.: Handbuch der Fertiguestechnik, Band. 2/23, Carl Hausen Verlag, München, Wien, 1983.

[6] The competition for automotive connecting rod markets, Elsevier Science, Special Feature, May 2001.

[7] Visser D.: A comparision of Manufactoring Technologies in the Connecting Rod Industry, Submisssion to FIERF 06-06-08.

ANNALS of Faculty Engineering Hunedoara

– International Journal of Engineering

copyright © UNIVERSITY POLITEHNICA TIMISOARA,
FACULTY OF ENGINEERING HUNEDOARA,
5, REVOLUTIEI, 331128, HUNEDOARA, ROMANIA
http://annals.fih.upt.ro