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RECENT TRENDS ON RESEARCHES AND TECNOLOGIES IN FORGING PROCESSES IN JAPAN

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Abstract

The amount of production orders from Japanese car and construction machine industries have slightly increased in 2002, but the costs of the forged parts have decreased due to severe competitions with the other Asian countries. Most of the forging industries and some universities are making more efforts for technological researches and developments to meet the demand for higher accuracy and higher quality products, shortening of delivery time, and development of forged parts for new industrial fields. Some helical gears of which surfaces can be net-shaped have been started for commercial base production to be shipped to car industries. Some non-graphite lubricants for hot forging and some conversion coating free lubricants for cold forging have been developed to improve some environmental problems.

Key words: helical gears, net-shaped precision forging, non-graphite lubricants, conversion coating free lubricants

1. Introduction

Figure 1 shows a total weight of cold forged products used in a car in Japan during 1965-1990[1]. If a net shape ratio is defined by the weight ratio of forged and finished products to forged products, the net shape ratio has been steady states of about 80 % after 1975 in spite of about 100 % in 1965. This is because complicated shape products are difficult to form by a completely net shape forging.

The amount of production orders from Japanese car and construction machine industries have slightly increased in 2002, but the costs of the forged parts have decreased due to severe competitions with the other Asian countries. However, most of the forging industries and some universities are making more efforts for technological researches and developments to meet the demand for higher accuracy and higher quality products, shortening of delivery time, and development of forged parts for new industrial fields. Some helical gears of which surfaces can be formed by a net shape forging have been started for commercial base production to be shipped to car industries. Some non-graphite lubricants for hot forging and some conversion coating free lubricants for cold forging have been developed to improve some environmental problems.

2. Near net shape precision forging of complicated shaped products

In 1980's, an enclosed die forging without flash was developed in order to aim at simultaneous completion of filling up to die cavity at all contour portions of products [2]. By this method, inner races and tripods for continuous velocity joint and spiral bevel gears have been produced. The rolling surfaces of the inner races and the gear teeth can be net shaped completely.

In 1990's, an extrusion type forging has been used in order to form helical gears of pinion shafts as shown in Fig. 2[3]. The open front end causes large roll over at the top edge of the product, because the top edge is always open. The roll over can be suppressed and the extruded length can be homogenized by applying a certain level of back up pressure, such as scroll compressor parts as shown in Fig. 3[4].

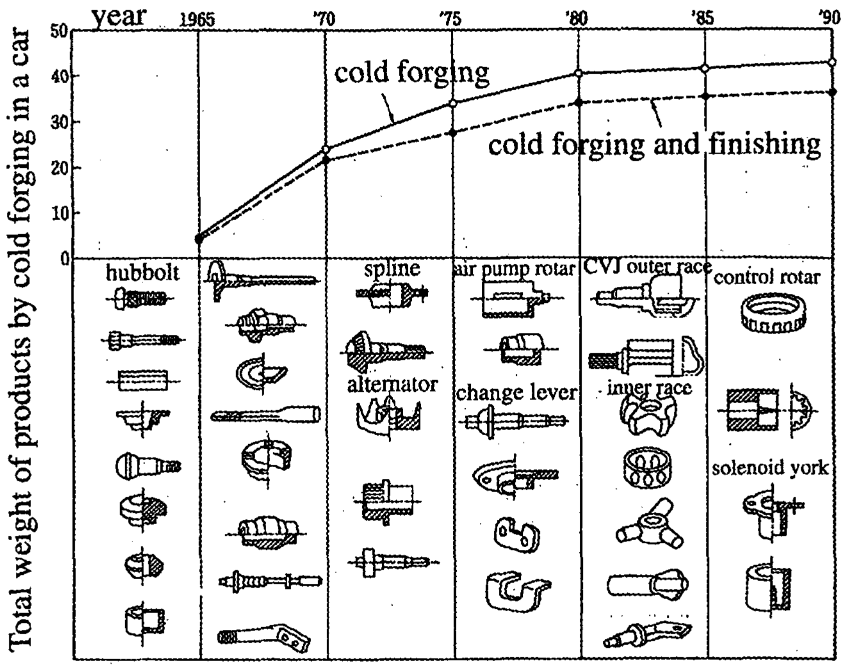


Fig. 1 Change of total weight of cold forged products used in a car in Japan during 1965-1990 [1]

Fig. 2 Helical gear of pinion shaft by extrusion type forging [3]

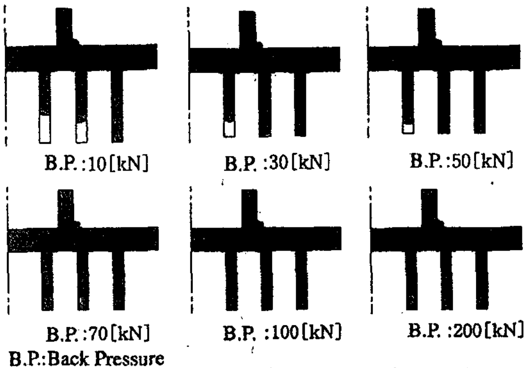


Fig. 3 Changes of extruded lengths in scroll compressor parts by extrusion type forging under different back pressures [4]

Kondo et al. has proposed a precision closed die forging utilizing a divided flow method as shown in Fig. 4 [5]. In the precision closed die forging, a relief hole is prepared in the blank and depressed by flat tools. During the depression, a centripetal flow occurs by the shrinkage of the relief hole and the divided flow is realized. In the actual divided flow method, a two step forging method is used, in which a conventional closed die forging is combined within low working pressure. A helical gear with boss, internal spline and grooves has been produced by this method as shown in Fig. 5 [5]. Figure 6 shows the comparison of tooth profile error and lead error between before and after heat treatment, respectively, for forged parts and machined ones. Although the scatter is a little large, tooth profile error of forged product is better than that of machined one. Lead error of forged product is a little worse than that of machined one.

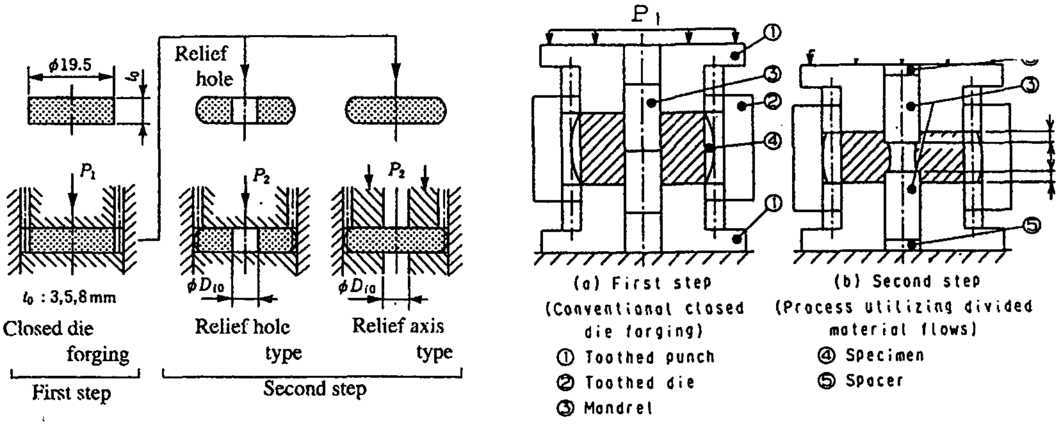


Fig. 4 Precision closed die forging utilizing divided flow method [5]

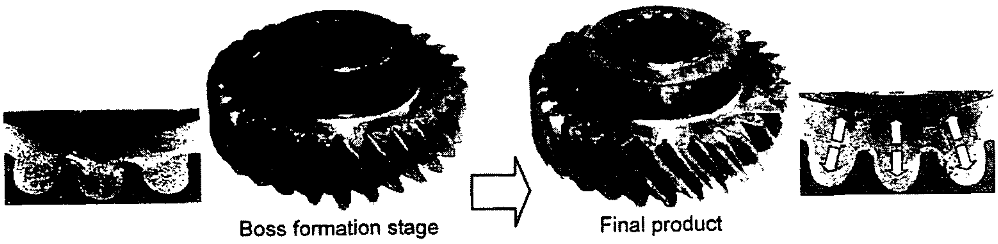


Fig. 5 Helical gear with boss, internal spline and grooves [5]

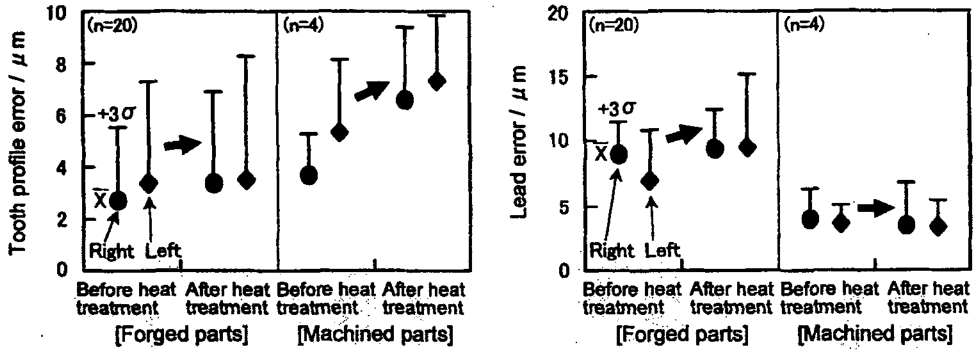


Fig. 6 Comparison of tooth profile error and lead error between forged parts and machine ones [5]

Ishida has developed a net shape cold forging process for forming helical gears and spline with crowned teeth as shown in Fig. 7 [6]. When the core die is forced into the taper die case, the core die deforms elastically, shrinking inward as it's pushed through the die case. The inward force forms the crowning on the gear teeth. When the core die is removed from the die case, it returns to its original form, expanding away from the part and enabling the crowned teeth to be removed easily from the die. Another unique aspect of the die sets is that they are equipped wit a mechanism to rotate the core die during the crown forging process. The friction caused between the core die and the work-piece helps create a homogeneous stress distribution and symmetrical crowing of the tooth flanks. It also allows for continuous metallic fiber flows at the gear root, providing high fatigue strength and pitting resistance. Figure 8 shows some samples of the products forged. Figure 9 shows the tooth profile error and the lead error after heat treatment for forged parts. The both of the right side and left side surface of the tooth have only tooth profile error less than 10 μm. The both of the lead crowning on the right side and the left side surfaces of the tooth has about 10μm. The process is capable of forming gear teeth JIS 2-3 quality for spacing error, lead error with crowning and runout.

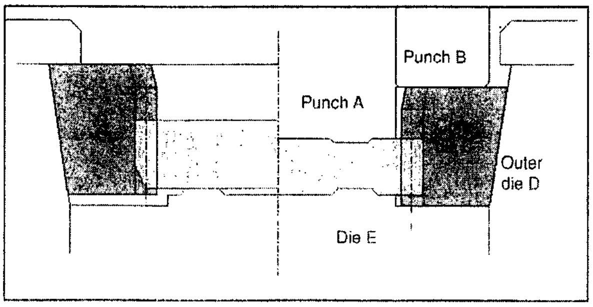
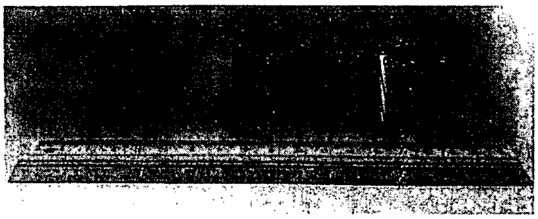
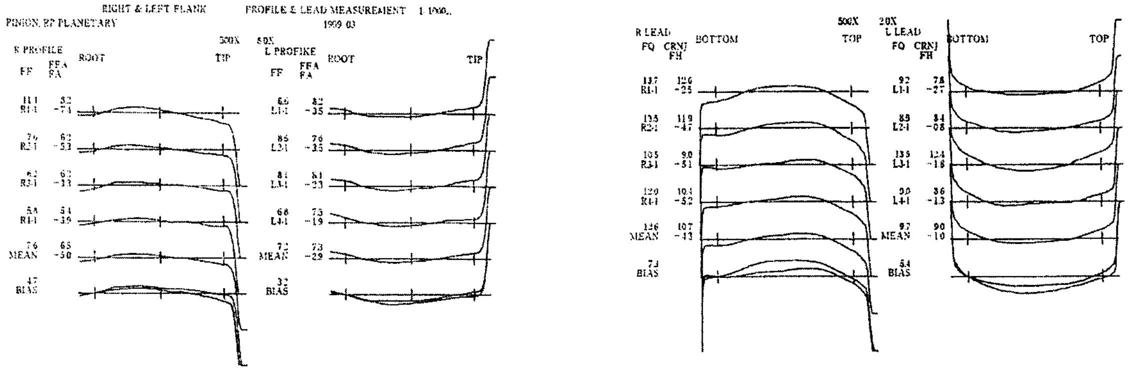


Fig. 7 Principle of net shape cold forging process for forming helical gears with crowned teeth [6]



Fist step Final step After machining

Fig. 8 Some helical gear products by the cold forging process [6]



Tooth profile Lead crowning

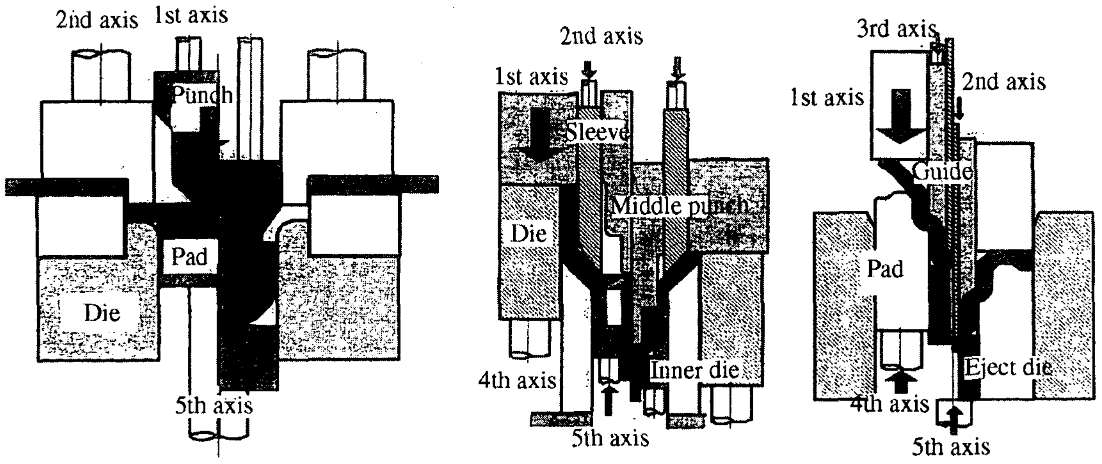
Fig. 9 Tooth profile error and lead error after heat treatment for helical gears forged by net shape cold forging process [6]

3. Precision forging combined with sheet metal forming

Figure 10 shows drawing and redrawing processes utilizing axial compressive force [9]. These processes have been developed to improve remarkably the redrawability with simple apparatus, because the work-piece is mainly redrawn with compressive stress by the outer punch. Figure 11 shows the three parts formed by the processes. The work-piece is a carbon steel sheet SPC 440 of thickness 1.6 mm. The product in which the flange portion is increased in thickness can be formed by only the three processes. These processes are considered to be a kind of precision forging with a sheet metal forming.

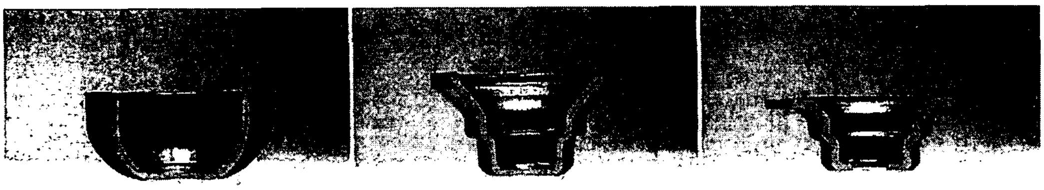
Figure 12 shows the other precision forging process combined with deep drawing and burring process [10]. Figure 13 shows a sample product with teeth formed by the processes. The work-piece is carbon steel sheet S35C of thickness 5 mm. In this case also, the outer rim portion was increased in thickness by compression and formed in gear by the extrusion type forging.

Recently, some sheet metal blanks can be forged to form various precision electric parts using a precision press which is driven by a servo-motor or a linear motor. We can call it a sheet metal forging. Figure 14 shows some samples of precision electric parts formed by forging with fine blanking process by the sheet metal forging [8].



1st step *2nd step* *Final step*

Fig. 10 Drawing and redrawing processes utilizing axial compressive force [9]



1st step *2nd step* *Final step*

Fig. 11 Three parts formed by the drawing and redrawing processes [9]

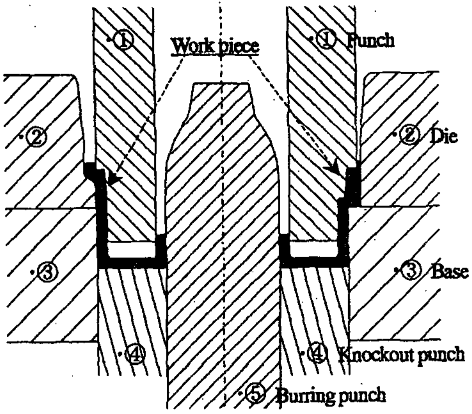


Fig. 12 Precision forging process combined with sheet metal forming [10]

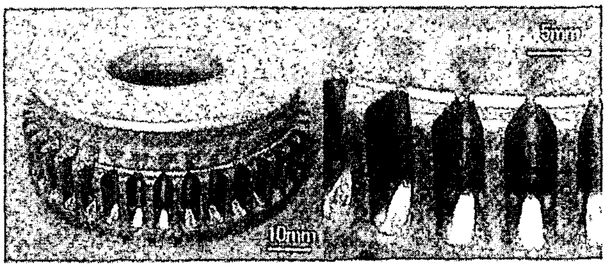


Fig. 13 Sample product formed by the process [10]

Fig. 14 Some samples of precision electric parts by sheet metal forging [8]

4. Tribological developments for environmental problems

Non-graphite lubricants for warm or hot forging processes have been developed to improve working environments from about 1985 in Japan. Figure 15 shows ratios of various kinds of lubricants applied for warm or hot forging in 1993 [11]. The applied ratio of non graphite lubricants was already 21 % in spite of ten years ago. Figure 16 shows the friction coefficients of a graphite lubricant and a polymer based non-graphite lubricant. The friction coefficient of the non-graphite lubricant gives approximately equal level as that of graphite lubricant when the non-graphite lubricant can be completely dried.

Figure 17 shows some kinds of hot forging products where polymer based non-graphite lubricants are applied [12]. The amount of hot forging products where the non-graphite lubricants are applied will be approximately 80 % in almost Japanese car industries.

Recently, some types of conversion coating free lubricant are developed to improve some environmental problems in cold forging processes in Japan. Some of the conversion coating free lubricants can be treated on work-pieces in a few minutes. Figure 18 shows some samples applied to the cold forging processes, such as drive pinion shaft [13]. Figure 19 shows the range in surface expansion ratio and a sliding distance where one of the conversion coating free lubricants is applied recently in car industries. The lubricant can be available within the ranges until the expansion ratio of 6 and thesliding distance of 500 mm.

It is difficult to perform successfully forging processes without any lubricant. However, some challenges are tried to do it. Osakada et al. have succeeded a backward can extrusion of magnesium alloy (ZK60) without lubricant under 300 °C as shown in **Fig. 20** [14].

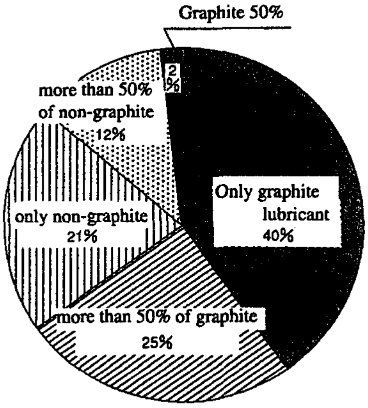


Fig. 15 Ratio of lubricants applied for hot forging in 1993 [11]

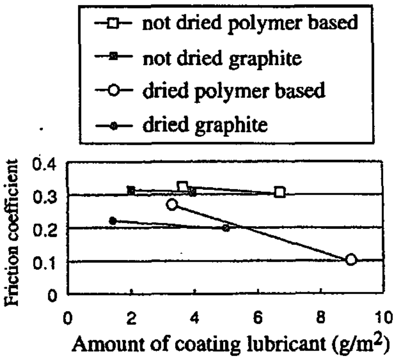


Fig. 16 Friction coefficients of graphite and non-graphite lubricants [11]

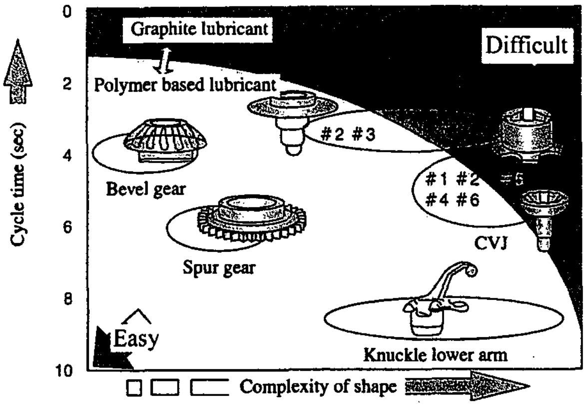


Fig. 17 Applicable range of polymer based non-graphite lubricant in hot forging processes [12]

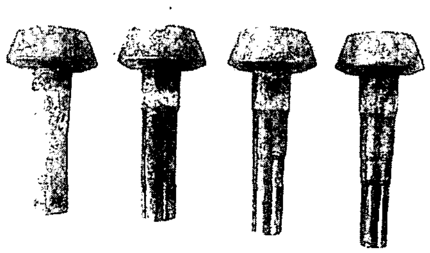


Fig. 18 Cold forging processes of drive pinion shaft lubricated with conversion coating free lubricant [13]

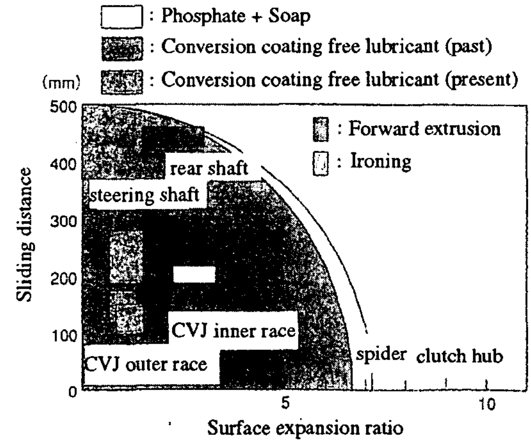


Fig. 19 Applicable range of conversion coating free lubricant [13]

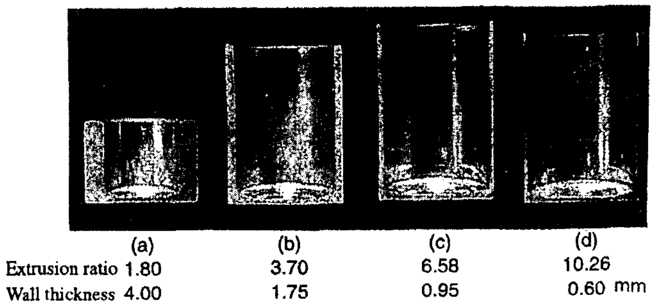


Fig. 20 Some examples of magnesium products forged without any lubricant[14]

5. Conclusions

Some symposium, seminars, and research meetings have been held in a year at the forging subcommittee of JSTP. We are discussing many challenging subjects besides the subjects described in this text. For examples, advanced FEM simulation, a flow forming and a spinning with increasing of thickness for small quantity production of many types of products, forging processes of titanium alloy and magnesium alloy, new functional gradient materials for long tool life, estimation of tool life in hot forging, CNC free motion presses driven directly by serve motor or linear motor, new friction testing methods, and etc. Most of the forging industries and some universities in Japan will make more and more efforts, in future also, for technological researches and developments to meet the demand for higher accuracy and higher quality products, shortening of delivery time, and development of forged parts for new industrial fields.

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