# DEVELOPMENT OF Fe-BASED METALLIC GLASS SHOT AMO-BEADS FOR PEENING WITH HIGH STRENGTH AND LONG LIFE

K. Okumura 1, K. Kajita 1, J. Kurosaki 1, H. Kimura 2,A.Inoue 2

1 SINTOBRATOR, LTD., Nagoya, Japan
2 IMR, TOHOKU UNIV., Sendai, Japan

**ABSTRACT**
Application of bulk metallic glass was examined as the shot peening media reforming technology of the material, much attention is paid to in these days. The intensity of an object product becomes strong and the shot used in connection with this also serves as high hardness. However, in order that toughness might tend to have crushed the conventional high hardness projection material low, the problem of increase of cost and the increase in generating of waste had produced it. Therefore, we have tried to solve these problems by applying the metallic glasses as shot. We have paid attention to Fe-based metallic glass system, and have searched for and found the best composition with high hardness and high toughness. Spheroidal particles made with the Fe-base metallic glass were used as shot for peening, and it was proved that this is of high hardness together with a long-life.

**KEY WORDS**
Shot Peening Media, Fe-base Metallic Glass, High Toughness, Long-Life, Mechanical Properties

**INTRODUCTION**
One of the key applications of shot peening is for materials improving the fatigue strength of various automotive gears and springs"(Y.Kojima,1988). In recent years, because the demand and requirement from all automotive manufactures for lighter weight and higher strength of parts are becoming stronger, the parts manufactures have to apply the various surface treatments such as carburized quenching and nitriding to achieve higher hardness on component parts.
Under these circumstances, the new shot media with higher hardness, produced from super hard alloy(cemented carbide steel alloy) are verified shot for the shot peening of automotive valve spring"(T.Ito,1988). However, in conventional crystal materials, the impact load carrying capacity (fracture toughness) deteriorates sharply along with the increase of hardness, and the high wearing rate of shot and the difficulty of maintaining stable peening conditions cast the serious problem.
To solve this problem, the application of amorphous alloy that features high hardness as well as high fracture toughness for peening abrasives was studied. In the past, bulk production of amorphous alloys was quite difficult because the formation of alloys was possible only by high speed cooling. However, in recent years, one of the present authors, Inoue and his group of Institute for Material Research (IMR) of Tohoku University discovered a number of alloys with high Glass Forming Ability (GFA) "(A.Inoue,1996). Based on the discovery of the high GFA alloys, the development of new Fe-based bulk amorphous alloy(Bulk Metallic Glass. BMG) was also challenged.

As one of application of the Fe-base BMG, it was succeeded to develop a highly functional blasting abrasives with high hardness, superior toughness and a longer service life never achievable by any conventional metallic or ceramic materials. This new blasting abrasives is trade-named as AMO-beads and was introduced to the industries. Fig.1 shows the hardness and service life of blasting abrasives made of conventional crystalline materials, where the expected service life-hardness relation of the Fe-base amorphous alloys is also inserted.

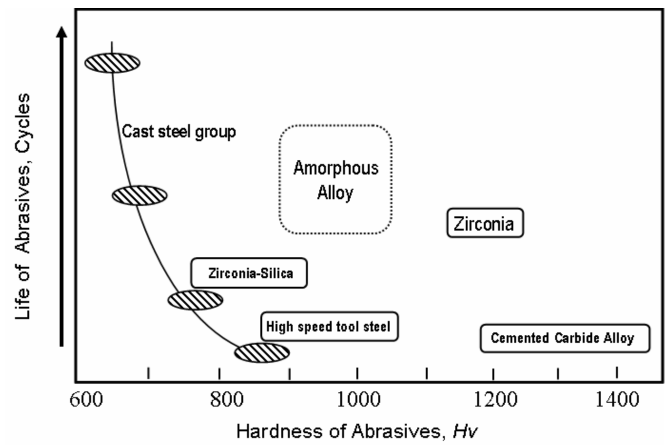


Fig.1 Life of conventional crystalline alloy blasting abrasives for commercial use plotted versus hardness and that of expected Amorphous Alloy Blasting Abrasives.

## METHODS＆RESULTS

### DEVELOPMENT OF MATERIALS

In view of cost advantage, it was focused the composition survey to iron base alloys to obtain amorphous phase of high hardness. GFA was evaluated from the structure appeared in the cross section of particles obtained by jetting out a fine molten metal stream into the stirred water. Fig.2 shows the optimum compositions range for amorphous phase formation in $(Fe_{1-x-y}Co_xNi_y)_{75}Si_8B_{14}Mo_3$(at%) alloy system keeping the quantity of Si, B and Mo constant.

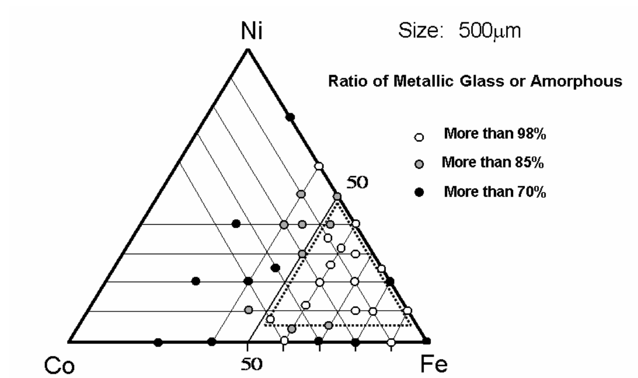


Fig.2 The Optimum composition range of Fe,Co and Ni for amorphous phase formation in $(Fe,Co,Ni)_{75}Si_8B_{14}Mo_3$ Alloy system prepared by melt ejection into stirred water.

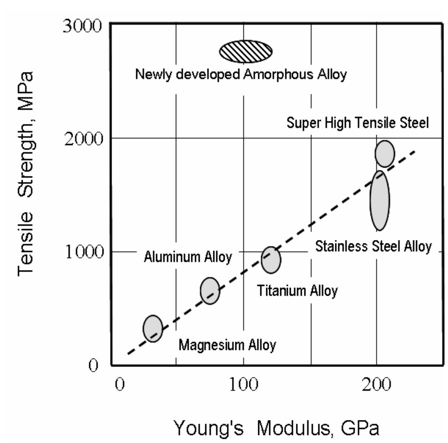


Fig.3 Relation between Young`s modulus and tensile strength of Fe-based metallic glass ribbons obtained in this work and a commercial crystalline materials,

The mechanical characteristics of Fe-base amorphous alloys obtained by the above survey were evaluated by using ribbon-shaped alloys produced single-roll process. The results are shown in Fig.3 where those of conventional materials are also shown for comparison. It is clearly shown characteristics peculiar to that amorphous alloys have higher tensile strength, lower Young’s modulus. They also had higher elastic limit elongation (2.2%) when compared to conventional crystalline materials. Accordingly, it can be said that newly developed alloys are fully capable to satisfy the requirements of blasting abrasives from the view point of its superior strength (high hardness) and high fracture toughness (high elastic limit energy).

## FEATURES OF Fe-BASE AMORPHOUS ALLOY BLASTING ABRASIVE

The newly developed blasting abrasives 'AMO-beads' using $(Fe,Co,Ni)_{75}Si_8B_{14}Mo_3$ amorphous alloy, have good properties such as corrosion resistance, hardness and the durability for impact fracture (high fracture toughness) particularly required for blasting abrasives. They are explained below.

(1)Microstructure

Fig.4 demonstrates the cross section of AMO-beads observed by optical microscope (OM) after being etched with a mixed solution of nitric acid, hydrochloric acid and acetic acid for 20s at room temperature. There is absolutely no contrasting crystal phase. The formation of highly uniform amorphous structure is observed.

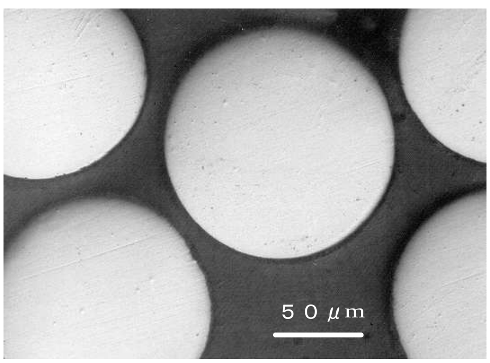


Fig.4 Optical mirograph of the cross-section of AMO-beads prepared by melt ejection method and eched in nitric acid, hydrochrolic acid and acetic acid for 20s.

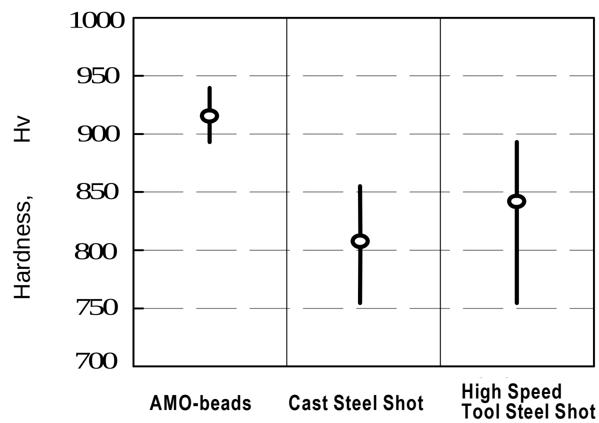


Fig.5 Vickers hardness(Hv) of cross-sections of AMO-beads, cast steel shot and high speed steel shot

(2)Hardness

Vickers hardness (Hv) of AMO-beads is compared in Fig.5 with other high hardness blasting abrasives. The hardness of AMO-beads is in the range of 900-950Hv, far above the hardness of conventional super hard type crystalline blasting abrasives. Moreover, the fluctuation of hardness in AMO-beads is minimal due to its highly uniform structure. The materialization of stable and extensive peening treatment effect is firmly expected.

(3)Service Life

The service life of blasting abrasive is represented by the fracture toughness of particles. For evaluating the fracture toughness, the particles are accelerated by compressed air and smashed against the target material made of high chromium cast iron (27%Cr, 600Hv), and the degree of fracture of the particles is compared. Pattern diagram of the device used for the experiment is shown in Fig.6. The blasting abrasive arranged in a constant size is made to circulate, and what became below the size is removed and the service life is evaluated from the residual ratio. The results of the life obtained are summarized in Fig.7. The service life of the high speed tool steel shot is assumed to be one in figure, and the service life of the AMO-beads are shown. For your information, the service life of the cast steel shot and the cemented carbide shot is shown.

From the experiment, it was verified that the fracture toughness of the blasting abrasives has been improved by applying new material to a large extent, and that the service life has been prolonged for 4 to 10 times compared with the conventional high hardness blasting materials.

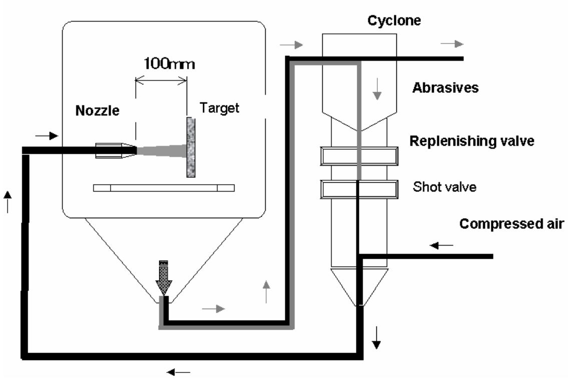


Fig.6 Pattern diagram of air blasting device for testing the service life of blasting abrasives.

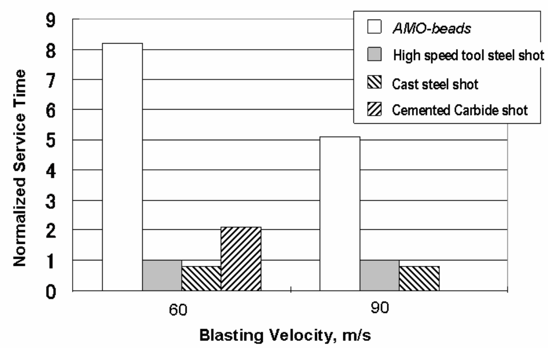


Fig.7 Service life ratios of AMO-beads, high speed steel shot, cast steel shot and tungsten carbide shot examined by air projecting method.

(4)Peening Characteristics

SKD11 (Fe-1.5mass%-12mass%Cr-1.0mass%Mo-0.3mass%V) is used as the test piece to be blasted. The peening characteristics of AMO-beads are compared with WC-Co cemented carbide alloy abrasives. The latter is considered as the highest grade in conventional commercial blasting abrasives together with zirconia ceramics abrasives. The test was conducted by gravity method and pressurizing method utilizing compressed air.

(4-1)Comparison by Gravity Method

The residual stress distribution and surface roughness by blasting abrasives, AMO-beads, zirconia and cemented carbide on SKD11 test piece in gravity method were summarized in Fig.8. The hardness of cemented carbide shot is 1400Hv and that of zirconia ceramics shot is 1200Hv; both have much higher hardness than that of AMO-beads shot. However, as shown in Fig.8, AMO-beads is not only capable of imparting high residual compressive stress to the test piece well comparable to cemented carbide and zirconia ceramics, but also capable of controlling the surface roughness to much lower than others. It is possible to achieve that AMO-beads possess the two key peening characteristics incompatible in any conventional crystalline alloy blasting abrasives.

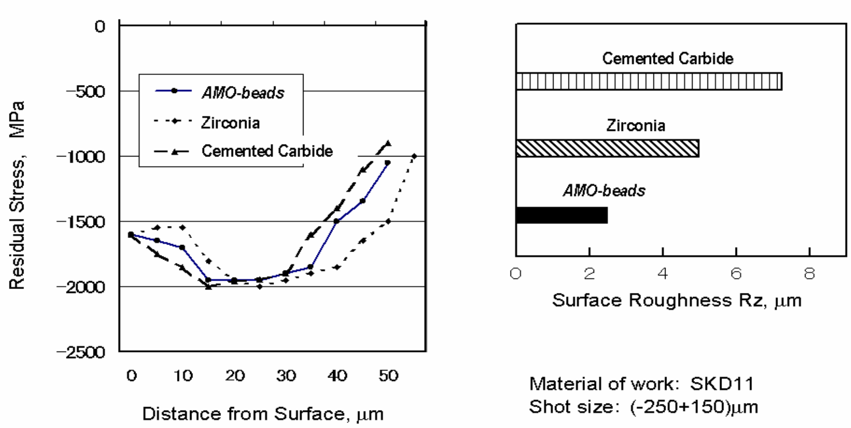


Fig.8 Peenig characteristics of AMO-beads tested by gravity method

(4-2)Comparison by Pressurizing Method
Next test is the comparison of residual stress distribution on SKD11 test piece achieved by AMO-beads and high speed steel shot (SKH55 equivalent, 850Hv) in pressurizing method. The result is shown in Fig.9. Vickers hardness (Hv) of AMO-beads is almost on the same level with that of the latter, but it is observed that the higher residual compressive stress is imparted by AMO-beads alloy shot into the deeper zone from the surface than high speed steel shot. In addition, as shown in Fig.7, the service life of AMO-beads is much longer than that of high speed steel blasting abrasive. From these results, it is firmly expected that a substantial peening cost reduction and a fair shortening of processing time by using AMO-beads.

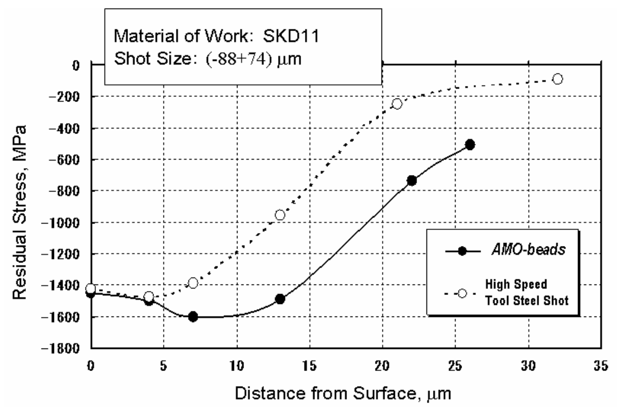


Fig.9 Relation between residual compression stress and distance from the shot surface of the tool steel (SKD11) sheet bombarded for 40s with AMO-beads and high speed steel (JIS-SKH55) shot by pressure method.

## DISCUSSION

The application of bulk metallic glass type iron-base alloy, entirely new material for blasting abrasives, made it possible to develop the characteristically superior blasting abrasives for shot peening that was quite impossible by conventional crystalline materials.

The full-scale practical application has just started. Application to automotive gears, shafts and valve spring is being studied. At the present moment, the application to the peening treatment of component parts of high power output and high strength requirement is beginning. It is anticipated that the requirement to design smaller parts will grow and it will become much severer along with the energy-saving trends, and it is expected that the needs of peening treatment for the materials with extremely high hardness will also become the matter of common practice. In this sense, it is possible to say that the development of amorphous blasting abrasives having hardness enough to cope with such trends of industries is just in time.

## CONCLUSION

As a result, applying Fe-base amorphous for the peening shot, the following conclusions are obtained.

(1)The newly developed blasting abrasives ‘AMO-beads’ using $(Fe,Co,Ni)_{75}Si_8B_{14}Mo_3$ amorphous alloy, have a good properties such as corrosion resistance, hardness and the durability for impact fracture(high fracture toughness) particularly required for blasting abrasives.

(2) The characteristics of ‘AMO-beads’ are follows.
The hardness is in the range of 900-950Hv.

The service life has been prolonged for 4 to 10 times compared with the conventional high hardness blasting materials.

(3) It is possible to claim that AMO-beads possess two key peening characteristics (higher residual compressive stress and lower surface roughness) incompatible in any conventional crystalline alloy blasting abrasives.

**REFERENCES**

Y.Kojima, Y.Miwa and S.Shibata et al, Auto Technology, Vol.42, No.6(1988), pp.755-760(in Japanese).

T.Ito, E.Ngashima and Y.Ishikawa et al, Transactions of JSSR, No.43(1988),pp.23-30(in Japanese).

A.Inoue, Function & Materials,Vol.116,NO.5(1996),pp.5-13(in Japanese).