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Design Improvement Study For cBN Coated Cutting Body Used In Piston Ring Cutting Process

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ABSTRACT : *In this study, the quality of non-alloy, non-heat treated, gray cast iron workpieces with lamellar graphite was compared with the cutter body with cubic boron nitride (cBN) coated with different hot work steel tool designs.As an alternative to the current single piece cutter body design, a multi-piece modular cutter body has been designed and used.Cutting process is done with INDEX brand automatic CNC cutting machine. Cutting heights and parallelism of the produced samples were measured with GOETZE special design ring height measuring device and surface roughnesses were measured with MAHR brand MARSURF XR1 model surface roughness meter.It has been found that two different body designs also produce similar results on product quality.No significant difference was observed between the ring height, parallelismand surface roughness values.This result shows that the newly designed multi-piece modular cutter body can be used while maintaining the current product quality.In this way, by using the multi-piece modular cutter body, it will be able to reduce setup time, cutter tool scrap rates and cut off all product dimensions with minimum stock level.*

KEYWORDS *–cBN coating, cBN cutter body, gray cast iron, hot work tool steel, modular design.*

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I. INTRODUCTION

Today, piston rings have a great effect on the efficiency of internal combustion engines.This ratio is 20-30% when considering mechanical power loss due to friction [1].The functions of the piston rings that perform cooling, sealing and oil consumption control functions are increasing day by day and cause the development of many new ring designs.In addition, the necessity of improving the mass production conditions has arisen to meet the increased demands, and the multiple casting and splitting of the piston rings has emerged as a result of these requirements.

During operation, the piston ring, which is in continuous friction with the cylinder liner, must lubricate the environment in order to prevent the metal wearing, ie, a thin oil film between the cylinder liner and the piston ring to reduce friction.The piston rings provide a thin oil film formation on the cylinder wall by scraping the excess oil.Thus, they both lubricate the cylinders and prevent the engine from burning fat [2]. Pison rings that fulfill a significant part of this task are called scraper and oil control rings.

Today, although the use of steel as a ring material is widespread, cast iron continues to be used extensively as a ring material.The reason for this is that cast iron materials are resistant to friction, wear resistance and heat transmission capacities are high [3]. Oil control rings and scraper rings are usually produced from lamellar graphite cast iron materials with hardnesses ranging from 97 ÷ 108 HRB.

Looking at machining technologies, the grinding process is now considered not only the last process, where modern machine tools have high cutting speeds at high points and require high rigidity.In addition, with grinding processes it is possible to obtain an acceptable finished product surface in abrasive mechanical processes with high stock removal [4]. In this context, in such grinding operations where high stock removal ratio can be obtained in production with small production parties, single layer super abrasive cutting discs are advantageous in terms of efficiency and cost [5].The production of single-layered superabrasive cutting discs is typically done with nickel electroplating which does not cause residual stresses due to low coating temperature

[6].

Two cutter bodies with alternate designs used in this study have nickel electroplating coated cBN (cubic boron nitride) coatings.In the experiments, one-piece and multi-piece alternatives of cBN-coated cutter bodies, which perform the splitting process by cutting the multiple castedpiston rings in the production, have been tried.In the trial run, spacers placed between each cutting disc were produced separately and used.The differences between the multi-piece modular design and the existing design cutting bodies were examined with the effect on the quality of the finished product and the cutting bodies were compared accordingly.

II. MATERIALS AND METHOD

In the experiments, non-alloyed, non-heat treated gray cast iron with lamel graphite was used as workpiece material (Hardness: 97 ÷ 108 HRB).Cutting body material is made of chrome-nickel-molybdenum-vanadium alloy, hot work tool steel which is resistant to repeated collision at high temperatures, has high toughness at high temperature, good fatigue resistance and oil or air hardenable.This cutter body material has cBN (Cubic Boron Nitride) coating on it.The experiments were performed with two different cutter body designs.The first design is a single piece cutter body that is currently used.Alternatively, a cutter body with a multi-piece modular design is used.

In this study, piston ring casting dimensions 82.4 / 72.3 x 14.4 mm (outer diameter / inner diameter x height) were used as workpiece.A casting ring with a height of 14.4 mm was cut and four 2.15 mm height piston rings were obtained.In this study, the balancing of the cutting bodies were performed by the HAIMER Balancing Machine, as shown in Fig.1 and cutting operation is done by automatic CNC cutting machine as shown in Fig.2.

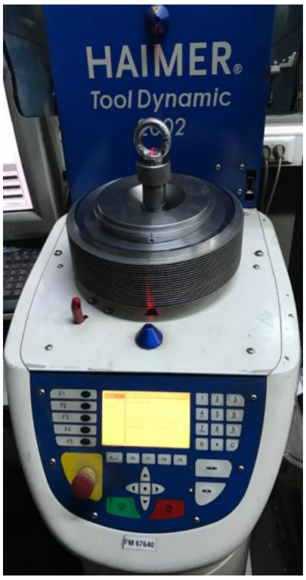


Figure 1:
HAIMER Balancing Machine

Figure 2:
CNC AutomaticCutting Machine

Cutting heights and parallelism of the produced samples were measured with GOETZE special design ring height measuring device and surface roughnesses were measured with MAHR brand MARSURF XR1 model surface roughness meter.The cut-off parameters used in the current production and shown in Table 1 were used for both trials without any modification.All dimensions and flange connection points are the same for both cutter body designs.

Table 1. Cutting Process Parameters

Cutting Speed	Feed	Cutting Oil
120 m/h	0,1 mm/rev	Castrol Ilocut

Figure 3 shows both cutting body designs used in this study.Experiments have been carried out with unused cutting discs.Figures 3.a and 3.c show the currently used single-piece cutter body (present design), and Fig. 3.b and Fig. 3.d show alternatively designed multi-piece cutter body (modular design) tools.

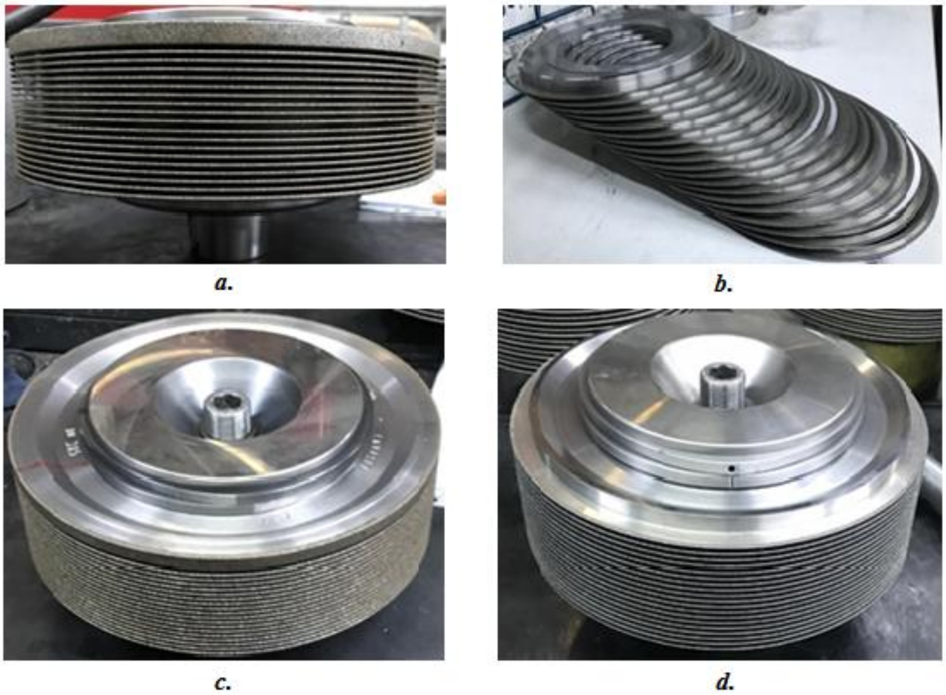
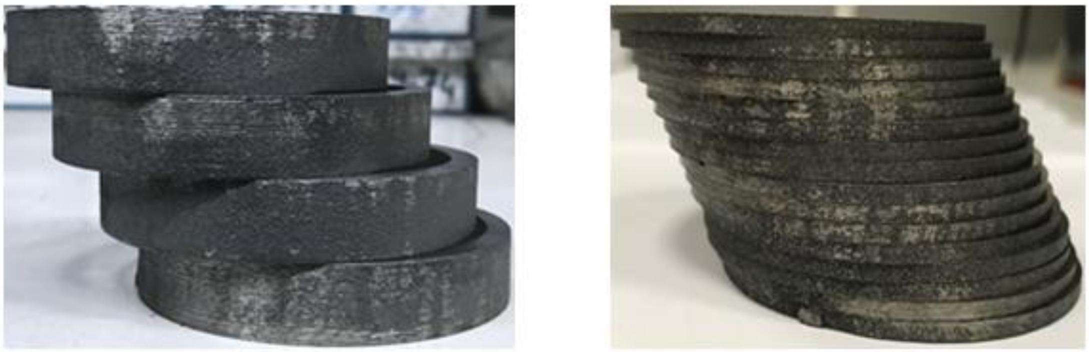


Figure 3:Cutter body designs;

a. Single piece cutter body front view (current design), b. Non-assembled multi-piece cutter body (modular design), c. One piece cutter body with flange connection (current design), d. Assembled multi-piece cutter body with flange connection (modular design)

III. RESULTS AND DISCUSSION

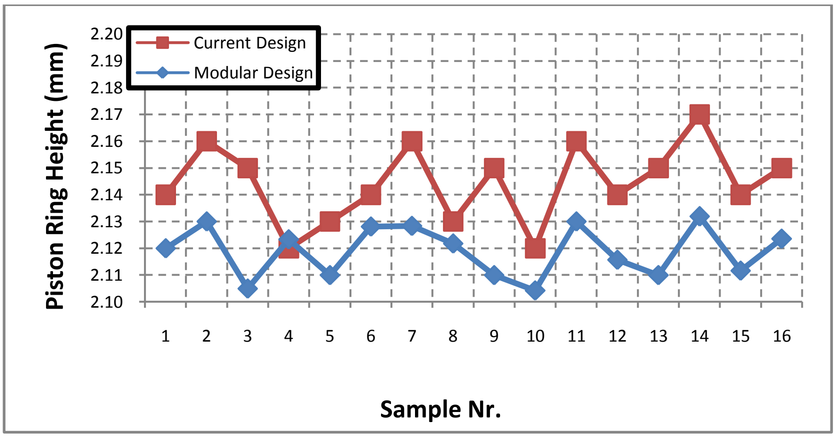
The tool and product dimensions, fixing tools, processed products and measuring equipments used in all the experiments in this study are the same.Firstly, current and newly designed cutting bodies were assembled with flanges and balances were taken on the HAIMER balancing device.After that, balanced cutting bodies fixed to the CNC cutting machine and cutting trials were performed with the parameters in Table 1.In both trials, 300 sample batches were cut from the same piston rings. Before and after splitted rings are shown in Fig.4. Fig. 4.a shows the whole piston ring packege that enter the process.As you can see, 4 pieces of multiple casted rings were cut and 16 piston rings were obtained from a package like Fig.4.b.Parallelism was measured by looking at the difference in height between the sections of 45 ° / 180 ° / 315 ° (from the circumference of 3 points) of the piston rings and the heights of the cutted pisto rings were also measured for each ring. In addition, Rz surface roughness of both lower and upper cutting surfaces of the cutted piston rings is measured.Measurements were taken over a total of 48 segments including 16 (1st package), 16 (2nd package) and 16 (3rd package) from the beginning of the process for a total of 300 sample production batches.Both cutter body designs were compared by taking the average of the cutted piston ring measurement results of all packages.



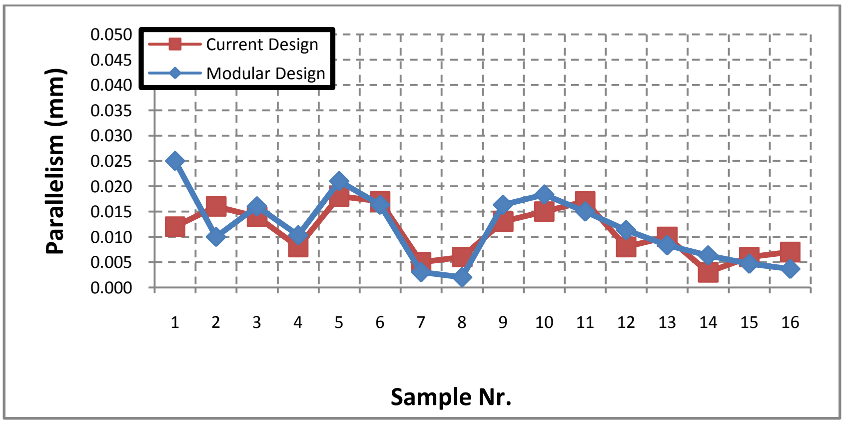
a. b.

Figure 4:Splitted piston rings;
a. Pre-Cut b. After Cutting

The results obtained for the ring height and parallelism are given in Fig. 5. The results obtained for the roughness of the cutting surfaces are given in Fig. 6.



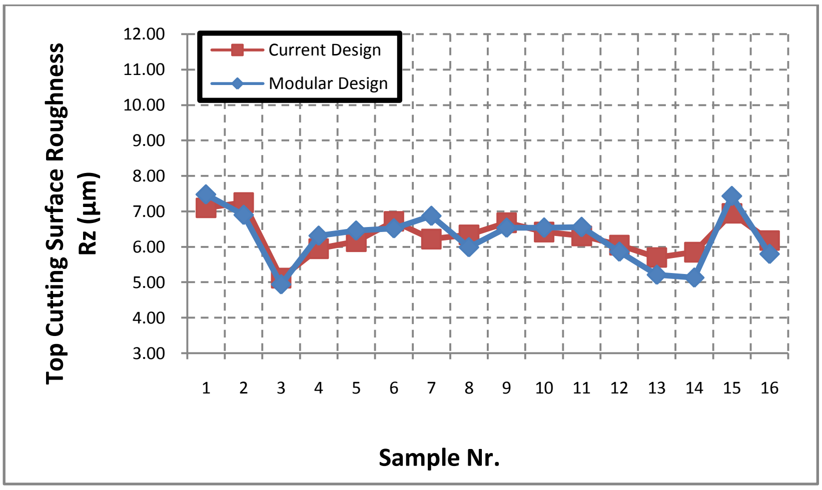
a.



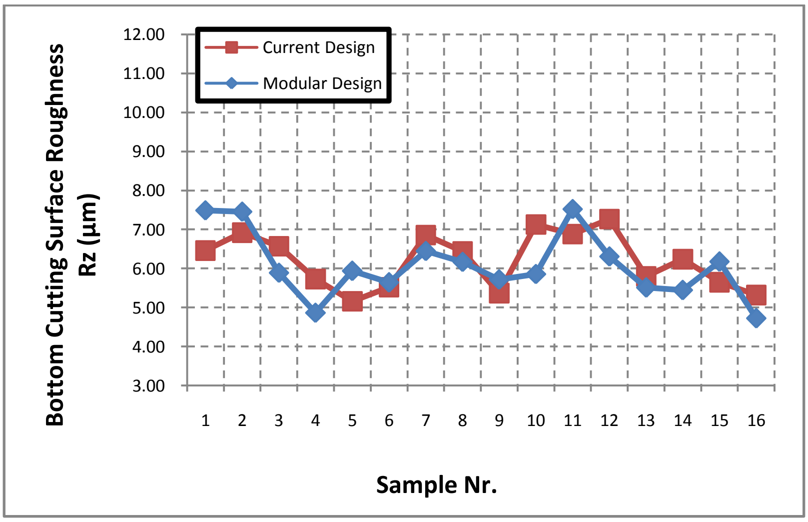
b.

Figure 5:
Piston Ring Height and Parallelism Measurement Results;
a. Piston Ring Heights b. Parallelism of the ring

The ring height process value shown in the graphic in Figure 5.a is 2,15 ± 0,05 mm.As seen from the results of both cutting boddies are within the process tolerances. However, the heights of the piston rings of the cutter body, which has a modular design, are lower tolerance.This is a specially designed situation. These cutting bodies coated with cBN with electrolysis process are getting wornstep by step during the lifecycle. Because of the this wear the piston ring height is moving to the upper band of tolerance. If the piston ring heights which cutted by new cutter bodystart atthe lower band of the tolerance, the life of the cutter body will be longer.It is much easier to adjust ring height with modular design because it is possible to setup all parts individually on the cutter body.Apart from that, ring heights with similar distribution are obtained.Figure 5.b shows that both cutting bodies can produce rings with similar parallelism.



a.



b.

Figure 6:
Piston Ring Cutting Surface Roughness Measurement Results
a. Top Cutting Surface Roughness b. Bottom Cutting Surface Roughness

The Rz roughness measurement results of the upper surfaces of the cutted piston rings in Fig. 6.a and the Rz roughness results of the lower surfaces are given in Figure 6.b.The surface roughnesses can be processed on both surfaces so as not to exceed Rz max.8 µm. As seen from the graphs of Fig. 5 and Fig. 6, similar height, parallelism and roughness results are obtained in both designs.No significant difference was found on the product quality and the results were obtained within the process tolerances with both cutting bodies.
The coating method or material of the two cutter body designs is not changed, but only in the new design the cutter body is divided into adjustable pieces.It has been found that the new design obtained by maintaining the dimesions in the existing one-piece cutter body design does not make any difference to the cutted product quality beyond the process specifications.

IV. CONCLUSION

The comparison of the new cutter body with the modular design and the existing one piece cutter body is given in Table 2.

Table2. Comparison Table

	Current Desing (One piece)	**New Design (Multi-piece/Modular)**
Scrap	Since a single piece is formed from a single body, any deformation causes the entire cutter body to be scrapped.	Since it is designed as a modular concept, the deforming discs are removed and replaced with new ones and the body continues to be used.
Cutting Height	There is a separate body required for each piston ring height.	Thanks to the modular design, the height of the spacers can be specially adjusted according to the height of the ring or the amount of chips to be thrown.
Stock	The cost of stock is high because different bodies are stocked for each different pisto ringt height.	The cost of stock is low because there are shared parts.

In this study, the quality of non-alloy, non-heat treated gray cast iron workpieces with lamellar graphite, the cBN-coated cutter body on the hot work tool steel with two different designs, and the cutted products were compared.Since the new modular design cutter body protects the connections of the present design without altering the machine connections in any way, the effect of the cutter body on the cutting machine has not been investigated.

It has been found that the multi-piece modular cuttingbody with improved design can provide the product quality up to the existing cutting body.According to these results, the utility of the new cutter body with this modular design has been determined without any quality problems.

Problems arising from the single body design can be overcome by passing the modular design.The most fundamental problem of the one-piece cutter body is that the entire cutter body must be scrapped in the event of any deformation.However, in the new design, it may be possible to replace only the deformable part.In addition, the modular design allows the cutter body to be easily adjusted to all cutting heights and to obtain different height combinations.Another advantage is stock cost.The height of the cutting discs is 90% identical.In the current design, a separate cutter body is needed for each different piston ring height.However, the modular design will reduce the number of stocks since the cutters with the same dimensions can be assembled to different bodies.For this reason, all parts can be replaced with the new design and the cost of the stock can be kept at a minimum level.

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