Thin Wall Austempered Ductile Iron Connecting Rod for Lighter Automotive Component - Production of Thin Wall Ductile Iron Connecting Rod

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Thin Wall Austempered Ductile Iron Connecting Rod for Lighter Automotive Component - Production of Thin Wall Ductile Iron Connecting Rod

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ABSTRACT

Lighter automotive components are produced to respond to global issue regarding energy. Lighter components can be achieved by replacing the material to those kno\\n as lighter material such as aluminium or applying thin wall casting technique. Lightweight automoti\'e components "ill mean lower fuel consumption. Based on the success in makino U1in wall ductile iron plate (TWDI) wi.th a thickness to I using a vertical casting, it encourages the implementation of the design to create lightweight automoti\'e components. The design \\a:> applied to produce a thin v.all two-cylinder engine ductile iron connecting rod which will be upgraded with austempering process. This connecting rod will be applied in Vespa PXI50. The designs \\ere simulated in Z-Cast simulation soft\\·are and analyzed to determine the most optimum design. The chosen design \\.as casted in a *founlily* to match the simulation. Evaluation of the characteristics will be run in U1e second stage of the research.

INTRODITCTION

Automotive components need lighter materials to reduce energy consumption . Scherem sho\\ed that cYery 250 lbs of weight reduction \\ill result in 1 mpg or fuei" sa\lng [I]. While Homtmg in Bockus stated that every 100 gr. reduction ofYehicle weight will save 0.5 liter or fuel for 100 kilometers [2]. Austempered ductile iron (ADI) is not a lightweight material but when thin wall casting method \Yas applied, ADI can compete \\ith lightweight materials. Martinez has combined thin wall casting technique with ADI to produce connecting road as presented by Fig. I [3].

Figure I. Hollm' Connecting Rod -Martinez (3]

Thin wall casting (TWC) is defined as a casting with maximum thickness of 5 nun hy Caldera f 4] and 3 *mm* by Stcfanescu [5]. TWC application in ductile iron (FCD) will produce thin \Yall ductile iron (TWDI). TWDI through austempcring process produces thin wall austcmpered ductile iron (TWADI). The thinnest TWDI thickness produced \\as 1 mm in the form of plate f6,7]. Martinez applied it by creating TWADI hollow connecting rod for two-cylinder engine \\"hi.ch produce 55 HP (40 kWh) at 5500 rpm [3). This hollow connecting rod caused 100 i?,rams of "eight reduction . TI1c characterization results sho"ed that the hollow connecting rod has similar abilities compared to the normal one.

Sudarsono et al. [6-12] dc\"cloped a Yertical casting design which produced TWDT plate with full ferrite matrix. Full ferrite matrix is required for TWADI. The design then applied to produce TWDI component. TWDI component produced ,,111 be used as a replacement of connecting rod in Vespa PX150. Vespa PXI50 is a motorcycle using two-cylinder engine which produce 5,8 kWh at 6000 rpm. So, the T\h'DI connecting rod must be able to act like the original one. The casting design to produce T\VDI connecting rod \\as presented [13] and the result of simulatilm process on the purposed casting desig11 showed that shrinkages \\ere found in both small and big ends of the nxl [13).

The research of thin wall austempered ductile iron (TWADI) c01mecting rod is di\'ided into 3 stages. This paper reports the result of the second stage. The aim or this stage is to reduce U1e defects from both ends by revising the casting design

RESEARCH METHODS

The research was diYided into three stages. In the first stage [13], characterization was applied to the original connecting rod. The characterization gave mechanical properties which should be fulfilled by the TWDI connecting rod. TWDT connecting rod design was also built in this stage. Modification was applied to the original connecting rod of Vespa PX150 (presented in Figure 2) to build the TWDI connecting rod design. The thickness of the I-\)Cam area was reduced from 4 to 3 mm as shown in Figure 3. The purposed design \\'as presented in Figure 4. Casting design was U1en made to produce the purposed design. The casting desig11 was built based on the patented casting design number

IDP000039503 [6-12] as presented by Figure 5. The casting designs were then analyzed using Z-Cast simulation. In the ::.econd stage, the casting designs \\Cre improved. The improYement was made based on the simulation rc ult of defects. The improvements \\ere made on shape and dimension of gating system. Casting yield was calculated for e\'ery design and the design that fulfill the requirement was produced in foundry „cale 10 \erifie<l the simulation result. fn the third stage, austempering process will take place.

Figure 2. Connecting rod of Vespa PX150

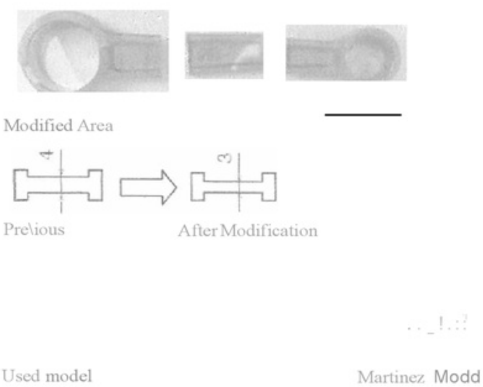


Figure 3. Modified. Area and Modification [13]

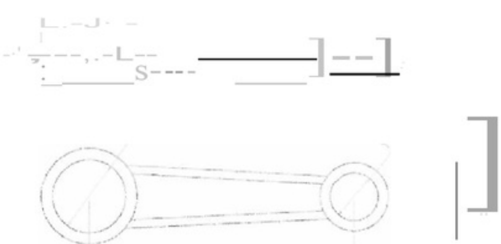
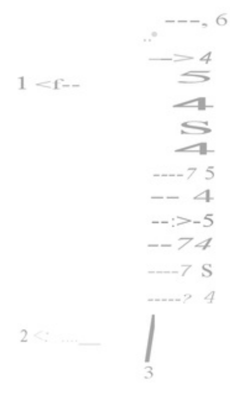


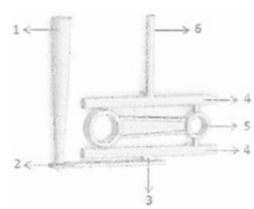
Figure 4. Dimension of the Rod. [13]

All the designs were simulated using Z-Cast simulation for filling, solidification and defocts. Z-Cast is a casting simulation de\'eloped by KITECH – South Korea . f1le simulation offers all functions to estimate the mold filling process and metal solidification. The boundary conditions of Z-Cast are l.ast matenal, mold material, pouring time, pouring temperature and heat transfer coefficient. The color scheme in simulation result for filling process indicates temperntme of molten metal. The temperature units are Celcius degree t°C) and degrade from white to blue color. Like in the filling prot:ess, color scheme in solidification process also indicates temperature and blue color in this process indicates phases changing from molten to solid metal. *As* in shrinkage process, blue and red color indicate sluinkage.

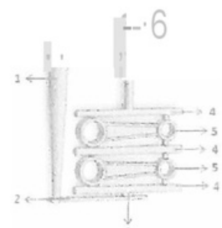
Design coding was presented in Table I. The coding was separated mto 2 categones. The first category, D-S 1 to D-*S4,* were used in the first stage. The differences of every design in the first stage laid on munbers of rod produced . S l for I rod. S2 for 2 rods, S3 for 3 rods and S4 for 4 rods for eYery mold. \\!bile the D-SlM to D-S4M were used for modified designs in the second stage.



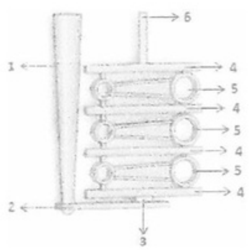
Design No. IDP000039503



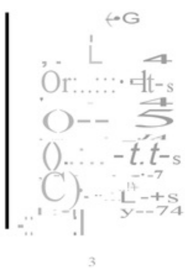
D-Sl



D-S2



D-S3



D-S4

Figure 5. Casting: Design [13] – I. Do\\n Sprne 2. Rwmer 3. Ingate 4. Riser 5. Plate or Connecting Rod 6. Gas TUillld

Table. 1 Design Coding

Code	Desc1iption	Stage
D-SI	Basic Design – 1 rod in 1 mold	Ist
D-S2	Basic Design - 2 rods in 1 mold	
D-S3	Basic Design - 3 rods in 1 mold	
D-S4	Basic Design - 4 rods in I mold	
D-SIM	Improved Design – I rod in 1 mold	2nd
D-S2M	Improved Design - 2 rods in I mold	
D-S3M	Improved Design – 3 rods in I mold	
D-S4M	Impro\'ed Design - 4 rods in I mold	

DISCUSSION

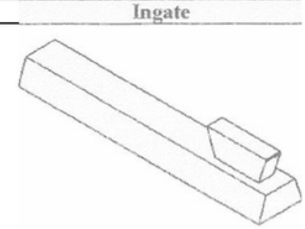
The design of TWDI cormecting rod developed in this research differs with Martinez [3). Martinez developed a hollow I-section connecting rod while this research deYeloped reduction of I-section thickness. This model was chosen due to strength and manufacturing process simplicity [13].

Characteri zation process [13] of the originaI rod showed that it i s made from chromium steel "ith 0,17% carbon , 0,80% chrom , 0,25% silicon. The microstructure is ferrite and chromium carbides. The standard ultimate tensile strength is 780 lv1Pa (hardened) , elongation is 15 % an<l F3rinell hardness number is 217 to 302 lv1Pa. The \Yeight is 136 gr.

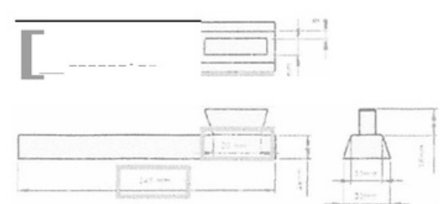
Dimension of the original connecting. rod was shmYed by Figure 4. Following the work of Martinez [3], thickne ss modification is applied in I-section of the connecting rod. Thus, dimensional changing only happened in the thickness or I-section. In this research the thickness is reduced for I 1mn. Casting design is calculated and built f13) based on the dimension of the original connecting rod except for the thickness of the I-section. Since the casting design is made based on Design No. IDP000039503, the connecting rod is placed bet\\een 2 cylindrical risers. As reported previously [13) the result of this sho\\"ed that shrinkage formed in the big end. To deal \Yith it , impro\'ements are made in the design by enlarging the dimension mgate and riser . The enlargement is applied to push the shrinkage formation in riser and shorten the pouring (filling) lime. The dimension of ingate and riser for original and improved designs are presented in Figure 6.

The sinmlation result for the improved designs were presented in Figure 7. And the comparison was showed in Figure 8 [13]. Simulation of filling showed that molten metal filled e\'ery part of the mold and lhe sign of premature solidification is not found. The molten metal temperature in ingate is high as shown by yellow to orange color. The lo""est molten metal temperature in ingate wa s presented by D-SIM, "hile the highest is in D-S4M Although D-SIM sho\\Cd the lmYest molten metal temperature in its ingate but the temperature is still high, marked by the red to orange color. Compared to the basic design, the improYed design has higher molten metal temperatures.

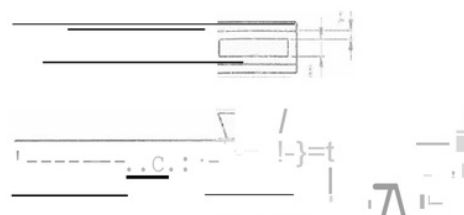
Ingate



Original Design



Im roved Desi n

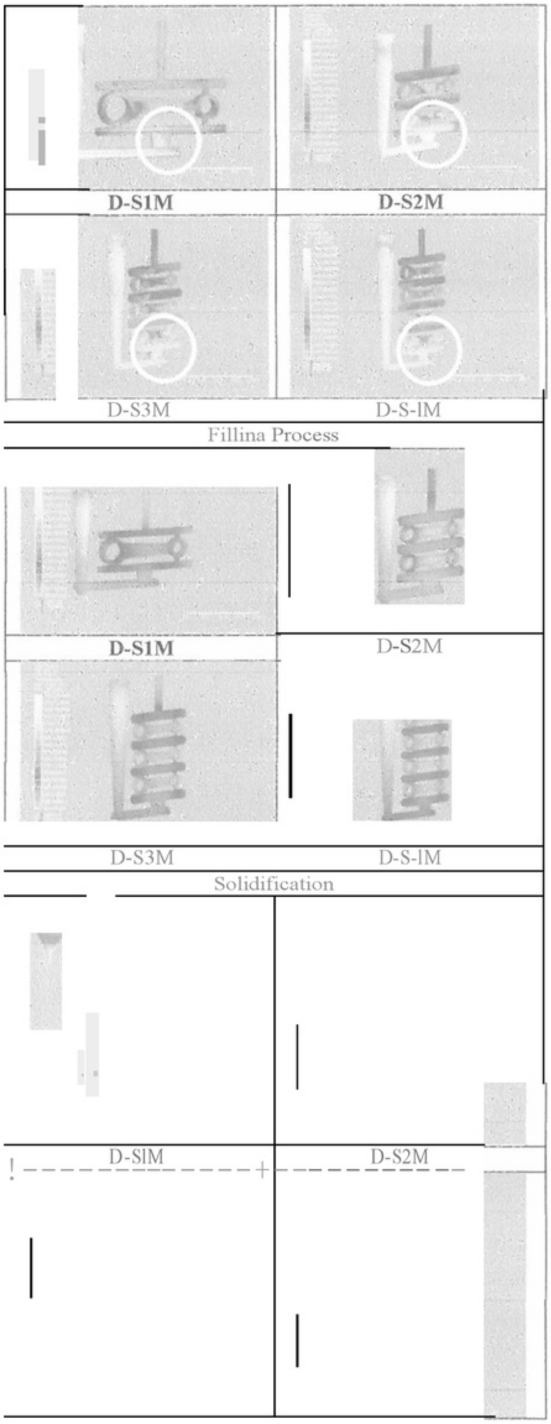


Risers

Original Design

Im roved Desi n

Fi w-e 6. l imensional Chan es.



Figw-e 7. Simulation Result for Improved Design

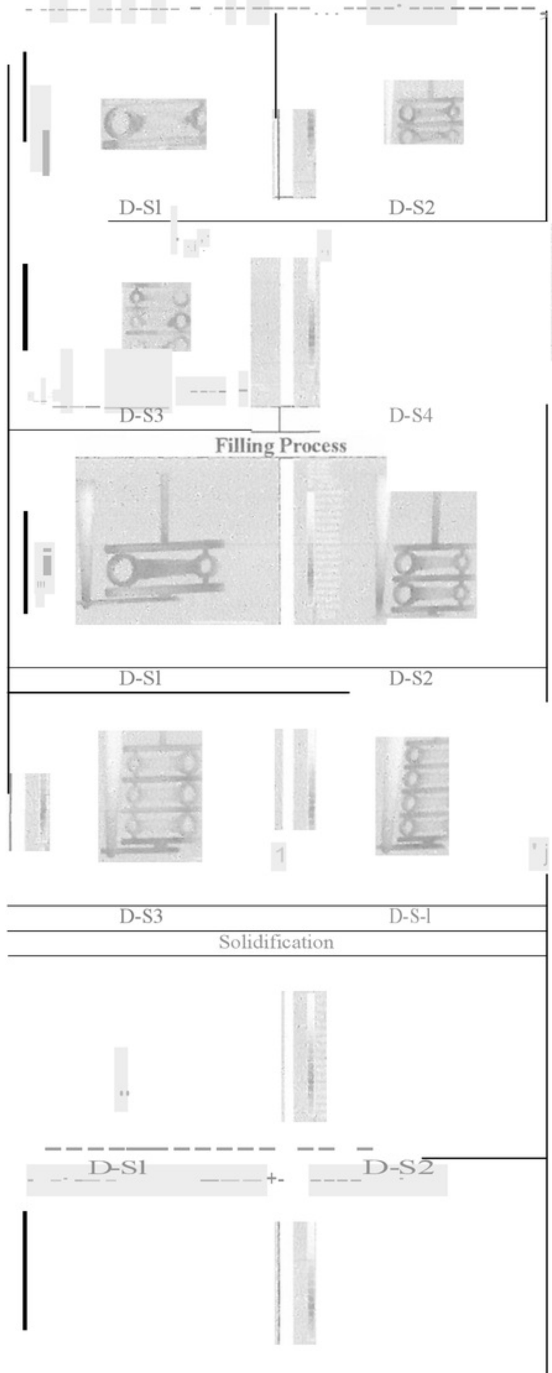


Figure 8. Simulation Result for Basic Desi ı 13

Solidification on the improved design showed that the last part to solidify is the riser. This result shtmcd that the formation of shrinkage \vill move to riser. ImproYed design has higher temperature in risers compared to the basic design as sho\m in Figure 8. Risers in improYed design ha\'e red color (Figure 7) \\hile in ba ic design their colors are blue. The distributions of solidification temperature were not significant that ensure the uniformity in the solidified structures. The first part to solidified was I-beam. Depletion process is applied in this area. The solidification temperatures between both ends tend to be sin1ilar. The distribution of solidification temperatures in U1e improved designs were more even compared to U1e basic design especially in both ends.

The result of shrinkage simulation showed that shrinkage formation in the improYed designs formed almost in risers. Shrinkages in the basic design is found in both ends while in the improYed design only found in one end. The in1proved design has much more shrinkages compared to basic design but most Of the shrinkage are formed in riser except for 0-S 1M Shrinkages in D-S!M, as well as D-SI, are formed in botil ends but still can be tolerated. Compared to D-S1, shrinkage in D-S1M are smaller. Enlarging diameter of tile riser delays its solidification process and allo\\'s the casting product to solidify first. This condition makes the riser feeds the casting product to compensate for solidification shrinkage and the shrinkages fonn in the risers. Figurc 7 shows that the shrinkage formed in big end of D-S2M, D-S3Mand D-S4M is large. But careful observation revealed that most of the shrinkage formed in tile risers. As mention preYiously, dimension of the connecting rod is constant. During improvement, changes are only made to the dimension of ingate and risers.

Table 2. Casting Yield-%

D-Sl	D-S2	D-S3	D-S4
51	43	40	31
D-SlM	D-S2M	D-S3M	D-S-lM
37	39	40	41

Casting yield is also knov.11 as casting efficiencv. It is calculated based on the weight of casting product to total casting weight and the unit is percentage. Total casting weight consists of casting products, risers and gating system weights. Higher casting yield sho\\'S higher efficiency in material usage. The casting yield for both basic and impro\'ed design were presented in Tahle 2.

The casting yield in t1le improved designs increase as t1le number of components increase. This is in reversed to the result of the basic designs. Casting yield in improved designs were not as high as the basic designs. The highest casting yield for improYed design was obtaincJ by D-S4M, which is 20% belO\\ the highest casting yield in basic design. Casting yield in the inlproYed design is lo\Yer than basic design because the dimension of ingatc and risers \\ere enlarged. Ingate and risers are part of gating system that increases the weight of total casting.

Detennination on the chosen design \\as based on the analysis of filling, solidification, shrinkage, casting yield and number of components produced. Altilough basic designs have higher casting yield and smaller shrinkage area but the shrinkage formed in the end parts. The selected design for casting process was taken from improved design \\hich is U1e D-S4M

The casting result was presented in Figure 9. As showed in Figure 9 not all components arc formed completely. The defoetiYe component was component in the top end as showed by Figure 10. This happened because the pouring process was not rnnning continuously. Temperature in the ingate dropped during the discontinuity and caused premature solidification that stop the flo\.v of molten metal.

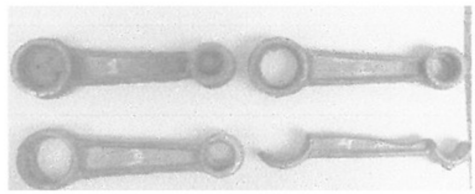


Figure 9. Cast Products

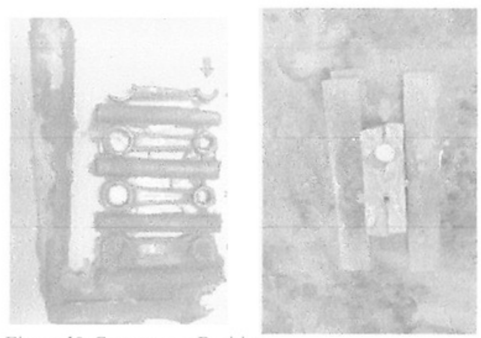


Figure 10. Component Position

Based on the calculation, the weight of TWDI connecting rod is 18.28 gr. Lighter U1an the original \\eight. The original weight of the connecting rod is 136.28 gr. and U1e TVl'DI co1U1ecting rod is 118 gr. The result of experimental \\Ork shoiYs that TWDI connt.-cling rod is lighter 36 gr. lighter. The original connecting rod is 136 gr. and the TWDI connecting rod is 100 gr.

CONCLUSION S

This study sho\Ys that the casting design ofTWDI plates can be applied to produce connecting rod component Improvements \\.ere made in casting designs and when tile simulation reported iliat premature solidification was not occurred and all parts can be fully charged, then tile last part to solidify \\as riser and shrinkage \\ere formed in riser. This is better compared to basic design. When the design \\'IIS put in production , the simulation result was confirmed h\' the casting product Defects occurred due to human error during the pouring. The weight reduce is 36 grams.

CONTACT INFORMATION

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