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The Effect of Zircon Filler Percentage, Viscosity, Coating Amount, and Agitation on The Fettling Duration of Track Shoes

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ABSTRACT

Metal penetration defects can slow down the fettling duration. This study examines the effect of zircon filler percentage, viscosity level, coating amount on the mold, and agitation on fettling duration in the metal casting process of the Komatsu PC2000 Excavator Track Shoe. The research method used was a True Experimental Post-test Only Control Design. The research samples were randomly taken from molds that were in production, and the data analysis technique used was descriptive statistics. Based on the results, changing the coating from 60% zircon to 80% zircon can reduce the fettling duration by about 10 minutes. If the viscosity of the 80% zircon coating is reduced to 55-60 Baume, the fettling duration can be shortened by up to 23 minutes. However, this would increase production costs by Rp. 38,532,900 per month. To address this, the coating mass on the mold was reduced by one-third, shortening the fettling duration by 20 minutes, with an additional cost of only Rp. 3,333,000 per month. Moreover, applying agitation to the 60% zircon coating can reduce fettling duration by up to 29 minutes without any additional costs.

1 Introduction

The Track Shoe is one of the key components of the Komatsu PC2000 excavator undercarriage, designed to distribute the machine's load to the ground surface, where the excavator makes contact with the soil and the moving base. This component is produced using metal casting techniques, specifically sand casting, which involves several stages such as molding, melting, shake out, fettling, heat treatment, inspection, and delivery. The quality of the Track Shoe is highly dependent on the geometric, physical, and mechanical qualities resulting from the metal casting process. However, during the casting process of the Track Shoe, several issues often arise, one of the most common being metal penetration defects, which can reduce the quality of the casting surface. Therefore, metal penetration defects must be cleaned from the surface of the Track Shoe using a grinding machine during the fettling process. As a result, the fettling process duration is extended, which delays the overall production flow of the Track Shoe.

Metal penetration can occur mechanically or chemically. Mechanical penetration is defined as the transportation of molten metal into the gaps between aggregate particles (voids between sand grains) in the mold due to excessive metallostatic pressure. On the other hand, chemical penetration is caused by a chemical reaction that forms fayalite (Fe_2SiO_4). This phase is formed when iron oxide (FeO) reacts with silica sand (SiO_2), resulting in the creation of fayalite [1].

Based on previous studies, coatings have been proven to help address metal penetration defects. The coating layer in the core shop or molding contributes only about 1% of the total cost of the casting component [2]. However, the use of coatings still incurs additional costs during the casting process, so their application needs to be carefully measured. The cost of applying the coating can be measured by the amount of coating applied to the sand mold. Unfortunately, in the case of Track Shoes, metal penetration defects still occur even though the sand molds (mold & core) have been coated with zircon coating.

Zircon is the most popular coating filler used for steel due to its high refractory specifications [3], with a melting temperature reaching 2727 ± 10°C. Refractory fillers must be highly fire-resistant and often contain a proportion of zircon and other materials with high density. This makes suspensions difficult, and sedimentation is always a problem.[4] However, based on observations, the coating that is ready for use is simply left to sit without any agitation process to keep the mixture uniform and eliminate non-homogeneous zones. As a result, within 10-15 minutes, the coating begins to experience sedimentation.

All the benefits of applying the correct coating can be lost if it is not mixed properly. The coating must be mixed until it is free of lumps and well-blended with its suspension components. Additionally, the coating needs to be controlled to maintain consistency in its application [5]. Baume is the most commonly used parameter by foundries to control coatings because it is quick and easy [6]. The Baume test is a simple test to help measure dilution consistency. Viscosity of the coating is usually reported in Baume degrees. A higher Baume number indicates a higher viscosity [7].

2 Method

The research method used is the True Experimental - Post-test Only Control Design, as presented in Figure 1. The research samples are randomly taken from Track Shoe molds that are in production (R), allowing all external variables influencing the experiment to be controlled. There are two types of research groups: the group that receives the treatment (X), known as the experimental group, and the group that does not, known as the control group. The experiment is considered to have an effect if the visual quality and fettling duration of the experimental group (Ox) are better compared to the control group (O5).

$$Ox < O5\text{: have effect}$$
$$Ox \geq O5\text{: do not have effect}$$

R	**X_1**	**O_1**
R	**X_2**	**O_2**
R	**X_3**	**O_3**
R	**X_4**	**O_4**
R		**O_5**

Figure 1. True Experimental - Post-test Only Control Design - Track Shoe

R : Random sample from the Track Shoe molds currently being produced
X1 : Replacing the coating with a zircon filler percentage higher than 60%, increasing it to 80% zircon
X2 : Varying the viscosity level of the coating to 55 and 60 Baume
X3 : Changing the mass of the coating application on the mold

X4 : Applying agitation to the coating with 60% zircon O1, 2, 3, 4: The results of the experiments for X1, X2, X3, and X4

O5 : The results from the control group, which will serve as the comparison

Next, the control group value (O5) will be compared with the experimental groups (O1, O2, O3, and O4). The fettling duration of the Track Shoe, based on the O5 test results, will serve as the reference value for this study. It is expected that each test result from the experimental groups will yield a smaller value than O5, indicating that the experiment has an effect.

The viscosity level of the coating is measured using the Baume scale with a hydrometer, while the amount of coating applied is measured with a scale in kilograms as it can be seen in Figure 2. To determine the amount of coating mass applied in the next treatment, an initial measurement is made by weighing the coating in the bucket before application, then subtracting the weight of the coating after it has been applied. The weight difference obtained becomes the standard for the amount of coating mass applied in the subsequent experiments.

(a) (b)

Figure 2. (a) Viscosity test and (b) mass scaling

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There are two data collection techniques used, namely observation and documentation. While the data analysis technique used is descriptive statistical methods. The experimental results will be presented in the form of graphs and then translated into easily understandable sentences.

3 Result and discussion

The experiment was conducted with multiple treatments to assess their effects on the fettling duration of the Track Shoe. The control group (O5) underwent the standard coating application and fettling process.

3.1 Standard coating

The standard coating process test is initially conducted on the control group O5 as presented in Figure 3.

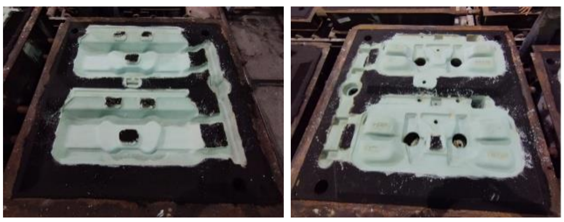

Figure 3. Coating Application for Control Group O5

Based on the test results, the control group O5 recorded a fettling duration of 59 minutes for the Track Shoe. The visual condition of the Track Shoe surface in the control group O5 shows the presence of metal penetration defects scattered in areas marked with red circles in Figure 4. The process of removing these metal penetration defects is what slows down the fettling duration of the Track Shoe.

Figure 4. Visual condition Control Group O5

3.2 The Effect of Zircon Filler Percentage on Coating

Additional treatments or changes were only applied during the coating application process on the Track Shoe mold. The coating on the first layer was changed to Teno ZKPX, a coating with a zircon content of 80%, while the second layer still used Isomol 330, a coating with a zircon content of 60%. The first and second layers can be seen in Figures 5 and 6. The viscosity level of Teno ZKPX is 80 Baume, which is the initial viscosity setting (factory/default) without any dilution, while Isomol 330 remains at 60 Baume.

Figure 5. First layer coating of group O1

Figure 5. Second layer coating of group O1

The experimental group O1 recorded a fettling duration of 49 minutes. However, the visual results of the Track Shoe casting in experimental group O1 showed the presence of coating residue adhering to the surface, which extended the fettling time. Nevertheless, the research results indicated that O1 < O5, meaning that the increase in zircon filler percentage to 80% in experimental group O1 had a positive effect, resulting in a 10-minute reduction in fettling duration compared to the control group O5 as it can be seen in Figure 6.

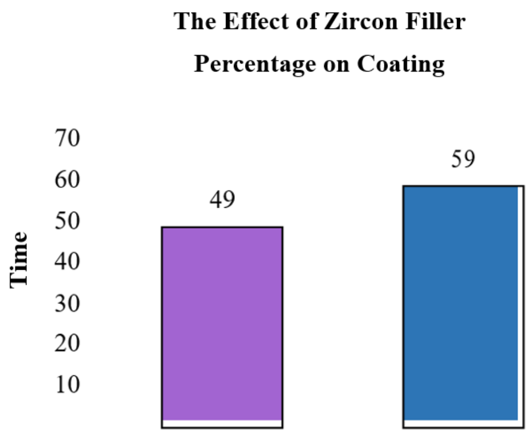

Figure 6. Comparison of fettling duration between experimental group O1 and control group O5

The treatment changes were applied only to the viscosity level of the Teno ZKPX coating, which was divided into two variations, 60 baume for $X2_1$ and 55 baume for $X2_2$. The first and second layer can be seen in Figure 7 and Figure 8. Meanwhile, the viscosity level of the Isomol 330 coating on the second layer remained at 60 baume.

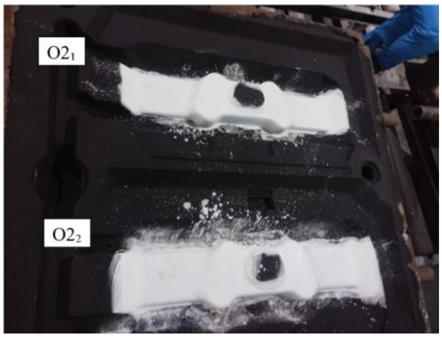

Figure 7. The first layer coating of experimental group O2

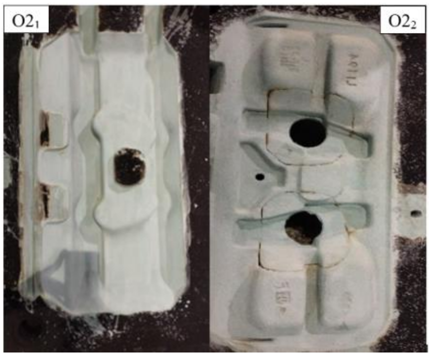

Figure 8. The second layer coating of experimental group O2

Experimental group O2 showed better results in terms of fettling duration for the Track Shoe compared to control group O5, as it can be seen in Figure 9. Group O21 recorded a fettling time of 40 minutes, while group O22 recorded 36 minutes. This resulted in a time difference of 19 minutes for O21 and 23 minutes for O22 when compared to O5.

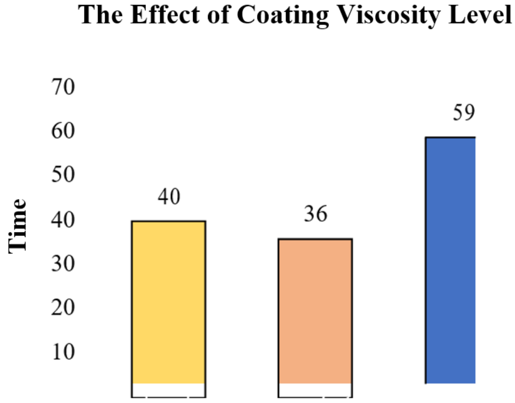

Figure 9. Comparison of fettling duration for track shoe experimental groups $O2_1$, $O2_2$, and control group O5

The visual results of the Track Shoe casting in the $O2_1$ experimental group showed the presence of metal penetration defects with leftover coating in the area marked in blue in Figure 14. However, these defects did not adhere strongly to the metal surface, making them easy to clean without taking much time. In contrast, the $O2_2$ experimental group did not show any metal penetration defects, but still left some coating residue adhered to the surface of the casting.

This observation indicates that the coating viscosity level has an impact on the fettling duration of the Track Shoe. While $O2_1$ (60 Baume) showed minor defects that were easy to remove, $O2_2$ (55 Baume) left more residual coating on the surface, which required more time for removal despite not having metal penetration defects. This suggests that lower viscosity (55 Baume) might result in better adhesion of the coating, leading to a slightly longer fettling time to clean off the coating. The comparison of visual surface condition of track shoe experimental groups $O2_1$ and $O2_2$ is shown in Figure 10.

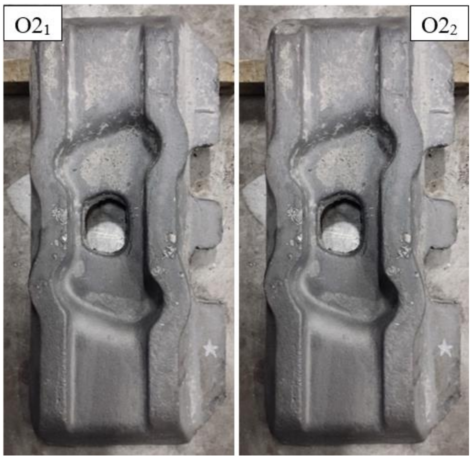

Figure 10. Comparison of Visual Surface Condition of Track Shoe: Experimental Groups $O2_1$ and $O2_2$

3.3 The effect of the coating mass quantity on the mold

The $O2_2$ experimental group achieved a reduction in fettling duration by 23 minutes. The next experiment was conducted by reducing the amount of coating applied to the mold to two-thirds of the original amount in treatment X3, while keeping the method the same as in treatment X22. The first layer used Teno ZKPX with 80% zircon content and a viscosity of 55 Baume. The second layer still used Isomol 330 with 60% zircon content and a viscosity of 60 Baume. The coating mass for the first layer was reduced by one-third, bringing it to 1.2 kg from the total of 1.8 kg, while the second layer remained unchanged. The results of the first and second layers of the O3 Experimental Group can be seen in Figure 11 and 12.

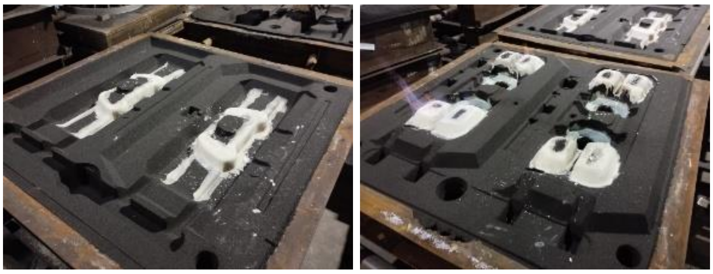

Figure 11. Coating of the first layer in the O3

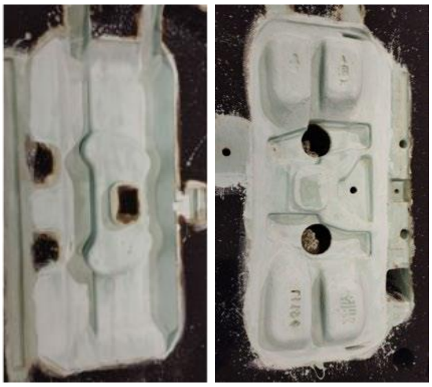

Figure 12. Coating of the second layer in the O3

The measurement results show that the fettling duration in the O3 experimental group was 20 minutes shorter than in the control group O5, with 39 minutes compared to 59 minutes, as shown in Figure 13. Although O3 was 3 minutes longer than $O2_2$, O3 was still effective in reducing the fettling duration of the Track Shoe. However, in the Track Shoe casting results of O3, a few metal penetration defects were found, such as areas circled in blue in Figure 14. This indicates that the amount of coating on the mold affects the fettling duration of the Track Shoe.

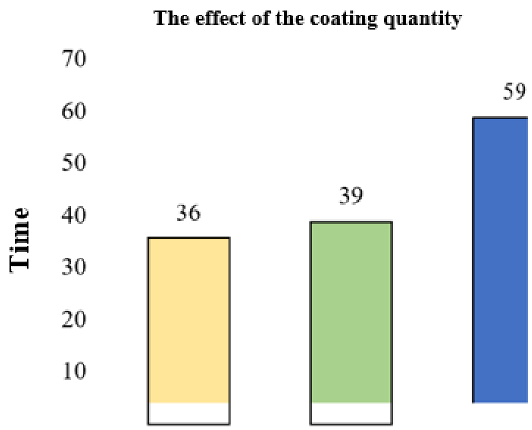

Figure 13. Comparison of fettling duration for track shoes in the $O2_2$, O3, and O5 experimental groups

Figure 14. Visual Condition of the O3 experimental group.

3.4 The effect of coating agitation.

Overall, this experiment was conducted in the same manner as the control group O5, with the first and second layers each using Isomol 330 coating with 60% zircon content and a viscosity of 60 Baume. The only difference is that in the O4 experimental group, a CPM (Coating Preparation Mixer) machine was added.

After adjusting the viscosity level, the coating was initially stored in a bucket. However, within a few minutes, the coating began to settle, as shown in Figure 19. The red line indicates the solvent liquid level, while the blue line shows the level of the coating (zircon), which started to separate. Now, with the CPM machine, the coating is no longer stored in the bucket, but is placed in a reservoir and continuously agitated to prevent settling.

Figure 19. Coating settling after 10 minutes

The coating preparation process in stages one to four, both before and after using the CPM machine remains the same, as follows:

a. Open the can and stir the coating using a drill mixer.
b. Gradually add 100 solvent
c. Stir the coating with the mixer while checking the viscosity of the coating using a hydrometer.
d. The above process is carried out gradually and slowly until the coating viscosity reaches 60 Baume.

In the fifth stage, before using the CPM, the coating will be divided into four buckets and stored in a cabinet. However, after using the CPM, in the fifth stage, the coating will be placed in a reservoir, and the CPM machine will be turned on, initiating the agitation process. The coating preparation is shown in Figure 20 and 21. While the coating application of the O4 experimental group is shown in Figure 22.

Figure 20. Coating preparation before using CPM

Figure 21. Coating preparation after using CPM

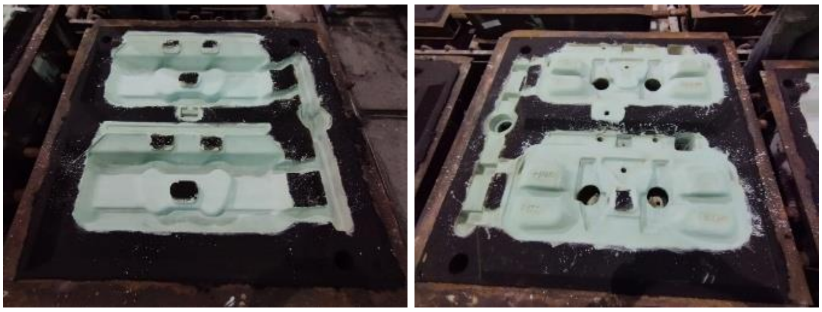

Figure 22. Coating application of the O4

Based on the measurement results, it was shown that O4 < O5, as shown in Figure 23. In the testing, the O4 experimental group recorded a fettling duration of 32 minutes for the Track Shoe, resulting in a 27-minute difference compared to O5. Additionally, the surface quality produced was very good, as seen in Figure 24, where metal penetration defects were no longer found, and no coating residue remained on the casting surface. Therefore, the fettling duration can be significantly shortened because there is no need to clean up such defects. The visual condition of experimental group O4 is shown in Figure 24.

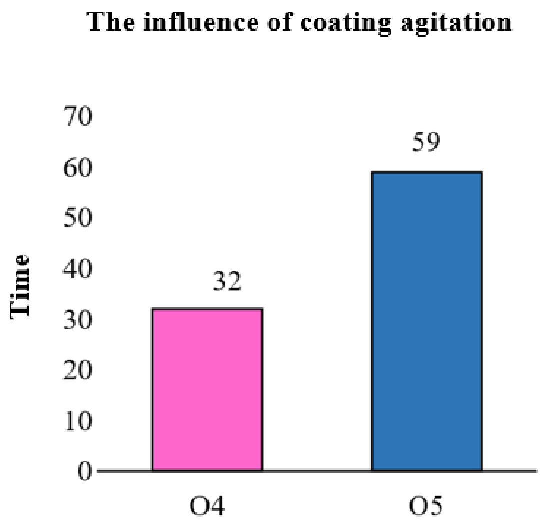

Figure 23. Comparison of fettling duration for track shoes in the O4 and O5 control group.

Figure 24. Visual condition of experimental group O4

4 Conclusion

The conclusion of this study is that the use of coating with an 80% zircon proportion is more effective in addressing metal penetration defects on Track Shoes compared to coating with a 60% zircon proportion. The viscosity level has a significant impact on the optimization of the applied coating. Additionally, changing the coating from a 60% zircon proportion to 80% may lead to an increase in production costs that is not proportional to the savings achieved. However, this can be mitigated by reducing the amount of coating applied to the mold. The application of agitation during the storage of 60% zircon coating can also reduce the fettling duration of the Track Shoe by up to 29 minutes, providing a similar effect without adding production costs. Further research can be conducted to gather more comprehensive and accurate data on the long-term impact of using agitation with 60% zircon coating.

Acknowledgements

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Conflicts of Interest

The authors no conflict of interest.

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