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Enhancing Wear Resistance of Grey Cast Iron Using Al_2O_3-13TiO_2 and Ni20Cr Coatings

Harjot Singh Gill[1], Gobind[2], Narinder Pal singh[3]
[1] *Department of Mechanical Engineering, Devraj Group's Technical Campus, Ferozepur*
[2]*Department of Mechanical Engineering, S.B.S.C.E.T Ferozepur*
[3]*Department of Mechanical Engineering, Chandigarh University Gharuan*

Abstract: *Wear is a common phenomenon in sliding parts. In wire drawing pulleys the friction between the pulley and wire leads to the wear of pulley. In this study Al_2O_3-13TiO2 and Ni20Cr coatings were prepared on different grades of cast iron (grey iron grade 250, high-carbon grey iron). These samples are investigated through standard procedure of pin-on-disk tests. The rotating disc at 1m/s is subjected to pressures of 30, 40, 50N. The samples were weighed before and after the test. And the results of coated samples were compared with the uncoated samples.*
Keywords: *Wear, Grey cast iron, coating, test.*

I. Introduction

Surface engineering deals with the surface design and performance of solid materials. The life of a component depends on the surface characteristics of engineering materials. Surface engineering can be defined as the branch of science that deals with methods for achieving the desired surface requirements and their behavior in service for engineering components [1].

1.1 Wear

Wear is the removal of material from one or both of two solid surfaces in a solid-state contact. It occurs when solid surfaces are in a sliding, rolling, or impact motion relative to one another. Wear occurs through surface interactions at asperities, and components may need replacement after a relatively small amount of material has been removed or if the surface is unduly roughened. In well-designed tribological systems, the removal of material is usually a very slow process but it is very steady and continuous [2].

Wear is caused due to many factors but friction is most important of them. Few more causes for occurrence of wear can be: Improper component design, Excessive Pressure, Contact area, Inadequate Lubrication, Environment, Material properties. Wear includes six principal, quite distinct phenomena that have only one thing in common: the removal of solid material from rubbing surfaces. These are (1) adhesive; (2) abrasive; (3) fatigue; (4) impact by erosion or percussion; (5) corrosive; and (6) electrical arc-induced wear

The wear resistance in the case of brake disc rotors, wire drawing pulleys etc. can be improved by a wide range of coatings. Thermal spray is a technique that produces a wide range of coatings for diverse applications. The principle of thermal spray is to melt material feedstock (wire or powder), to accelerate the melt to impact on a substrate where rapid solidification and deposit build-up occurs [3]. To reduce the wear problem, wear resistant coatings are deposited on the grey cast irons. Standard test methods for wear testing with pin-on disc apparatus are employed to study the wear behavior of the uncoated and coated grey irons as well. Thermal spray processes that have been considered to deposit the coatings are enlisted as: (1) Flame spraying with a powder or wire, (2) Electric arc wire spraying, (3) Plasma spraying, (4) Spray and fuse, (5) High Velocity Oxyfuel (HVOF) spraying, (6) Detonation Gun.

Among the commercially available thermal spray coating techniques, detonation spray (DS) is chosen to get hard, dense and consequently wear resistant coatings

1.2 Detonation Spray Process

The Detonation gun basically consists of a long water cooled barrel with inlet valves for gases and powder (Figure1). The overall set-up also includes an appropriate manipulator to hold the work piece and control its movements

D-gun spray process is a thermal spray coating process, which gives an extremely good adhesive strength, low porosity and coating surface with compressive residual stresses [4]. A precisely measured quantity of the combustion mixture consisting of oxygen and acetylene is fed through a tubular barrel closed at one end. In order to prevent the possible back firing a blanket of nitrogen gas is allowed to cover the gas inlets. Simultaneously, a predetermined quantity of the coating powder is fed into the combustion chamber. The gas mixture inside the chamber is ignited by a simple spark plug. The combustion of the gas mixture generates high pressure shock waves (detonation wave), which then propagate through the gas stream. Depending upon the ratio of the combustion gases, the temperature of the hot gas stream can go up to 4000 ^oC and the velocity of the shock wave can reach 3500m/sec. The hot gases generated in the detonation chamber travel down the barrel at a high velocity and in the process heat the particles to a plasticizing stage (only skin

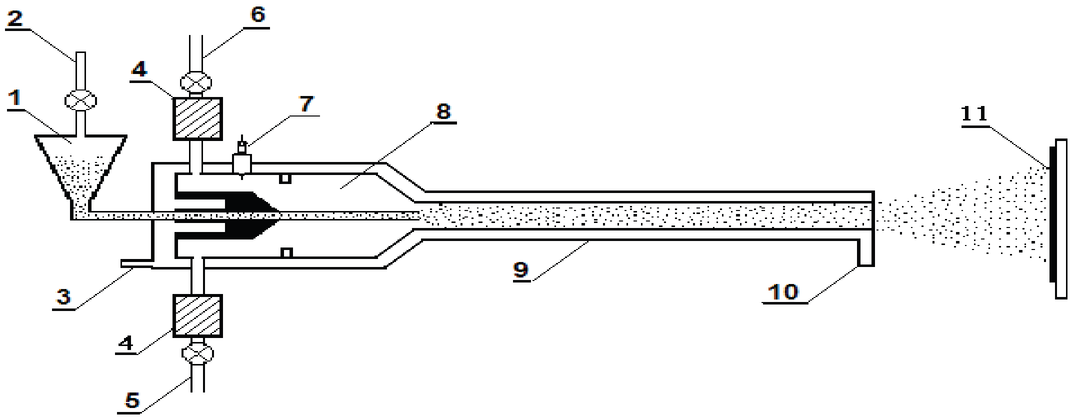

Figure 1: Scheme of detonation gun: 1 – coatings particles container; 2 – nitrogen; 3, 10 – cooling system; 4 – Safety valves; 5 propane-butane; 6 – oxygen; 7 – ignition system; 8 – detonation chamber, 9 – barrel, 11 – Substrate

melting of Particle) and also accelerate the particles to a velocity of 1200m/sec. These particles then come out of the barrel and impact the component held by the manipulator to form a coating. Depending on the required coating thickness and the type of coating material the detonation spraying cycle can be repeated at the rate of 1-10 shots per second. The chamber is finally flushed with nitrogen again to remove all the remaining “hot” powder particles from the chamber.

II. Experimental Procedure

Samples of cylindrical shape, with diameter 8mm and length 30mm were casted with the components of GI250 and GIHC. The grinding of end faces (to be coated) of the pins is done using emery papers and grinding was followed by polishing with 1/0, 2/0, 3/0 and 4/0 grades polishing papers. Two types of coating powders namely (1) Ni20Cr (2) Al_2O_3-13TiO_2 are selected for Detonation Spray Coating Process after the literature survey. Powder Ni20Cr and Al_2O_3-13TiO_2 form hard dense and excellent bonded coatings on the samples. The wear tests were performed in a machine (Wear and Friction Monitor Tester TR-201) conforming to ASTM G 99 standard. The wear tests for coated as well as uncoated specimens were conducted under three normal loads of 30 N, 40 N and 50 N and a fixed sliding velocity of 1 m/s. A track diameter of D=40 mm, sliding speed v=1 m/s is kept. Wear tests have been carried out for a total sliding distance of 5400 m (6 cycles of 5min, 5min, 10min, 10min, 20min, 40min duration). Weight losses for pins were measured after each cycle to determine the wear loss.

The coefficient of friction has been determined from the friction force and the normal loads in all the cases. The wear tracks produced in the coating were studied by XRD, SEM (FEI Quanta 200F), and The EDAX genesis software indicates the elemental compositions (weight %) present at point/area of interest. The results of coating volume loss are reported.

III. Results And Discussion

3.1 Comparative Wear Behavior for three coatings

The comparison of wear loss for the coatings; Ni20Cr, Al_2O_3-13TiO_2 on GIHC at 30N, 40N, and 50N is as shown in Figure 2. From the bar chart it is clear that Al_2O_3-13TiO_2 shows minimum CVL as compared to Ni20Cr coating. CVL for Al_2O_3-13TiO_2 is least at all the three normal loads of 30N, 40N, 50N, whereas highest CVL is found to be in bare GIHC substrate. CVL for both the detonation sprayed coatings is less than that to found in the in bare GIHC. The CVL for all the three substrate in increasing order can be given as: Al_2O_3-13TiO2 > Ni Cr > Bare GIHC Which means that Al_2O_3-13TiO2 coated substrate is most wear resistant among the three substrates and bare GIHC substrate is least wear resistant.

The comparison of wear loss for the coatings; Ni20Cr, Al_2O_3-13TiO_2 on GI250 at 30N, 40N, and 50N is as shown in Figure3. It is clear from the bar chart the Al_2O_3-13TiO_2 coatings is showing less CVL as compared to the Ni Cr coatings on the same substrate. The difference in CVL of Ni20Cr and Al_2O_3-13TiO_2 coatings is not much but still Al_2O_3-13TiO_2proves to be better wear resistant among the two at all three loads. The CVL for bare GI250 substrate is very high as compared to the coated substrate. Therefore the wear resistance of all three substrates in their decreasing order can be given as Al2O3-13TiO_2 > Ni20Cr > Bare GI250

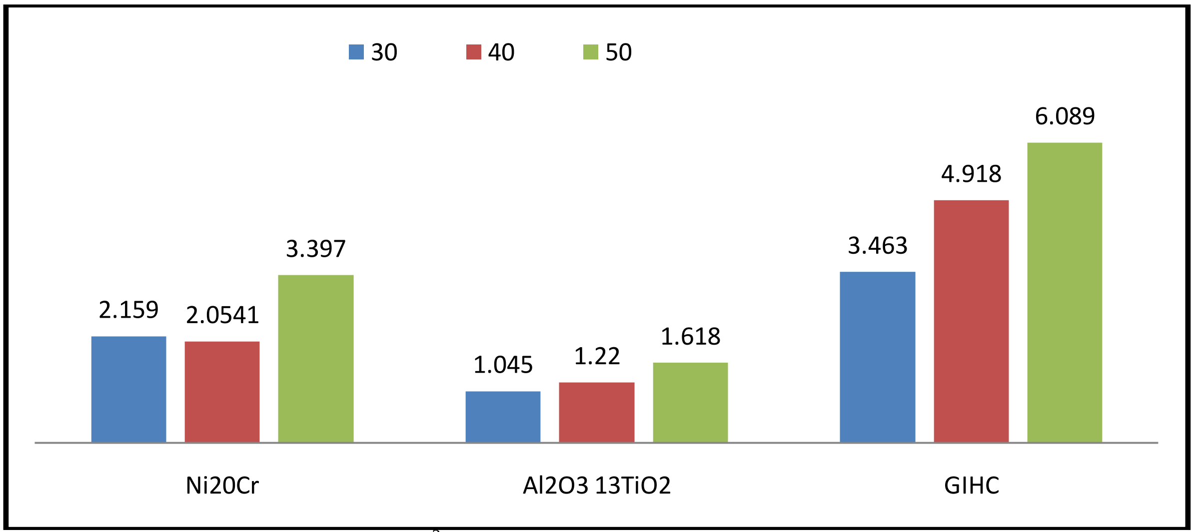

Figure 2: Cumulative Volume loss (mm^3) in one cycle for D-gun sprayed coatings and bare GIHC at 30N, 40N and50N**.**

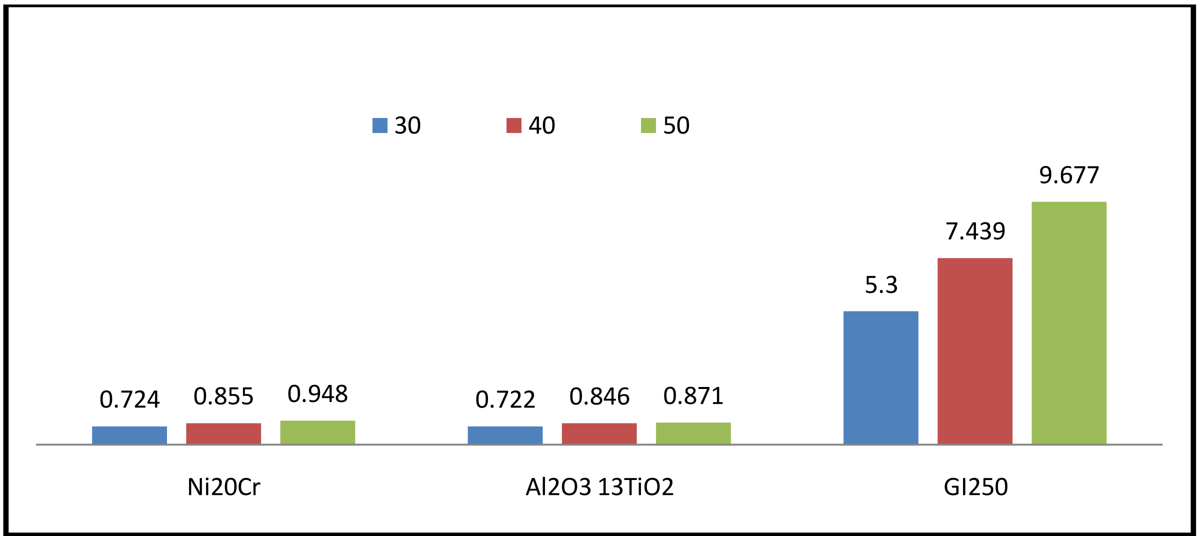

Figure 3: Cumulative Volume loss (mm^3) in one cycle for D-gun sprayed coatings and bare GI250 at 30N, 40N and50N**.**

3.2 SEM/EDAX Analysis

The SEM and EDAX analysis of the worn surfaces of (A) Ni Cr (B) Al_2O_3-13TiO_2 and (C) Bare GIHC substrate at normal load of 40N are shown in Figure 4. In general micrographs (in Figure 4) are very clear showing the peaks and elemental compostion. Grey and white area shows the unworn and worn out area respectively. Elemental composition corresponding to point-1 shows a area with the presence of Fe and C . The percentage Fe is high which indicates it is a worn out area. Similarly at Point-2 O is 50.38% and the surfae is identified as worn out due to the only presence of Fe, C and O. In the Figure B at point-3 grey area shows 16% Fe along with AL and Ti indicating it is less worn out area and at similarly at point-4 less wear is found with C as 17% along with the presence of Al , Ti components of the coating powder . In Figure C at point-5 and 6 there is high presence of Fe , C, and O indication it to be a totally worn out surface. High O and C indicate the presence of carbide and oxide of Fe on the surface.

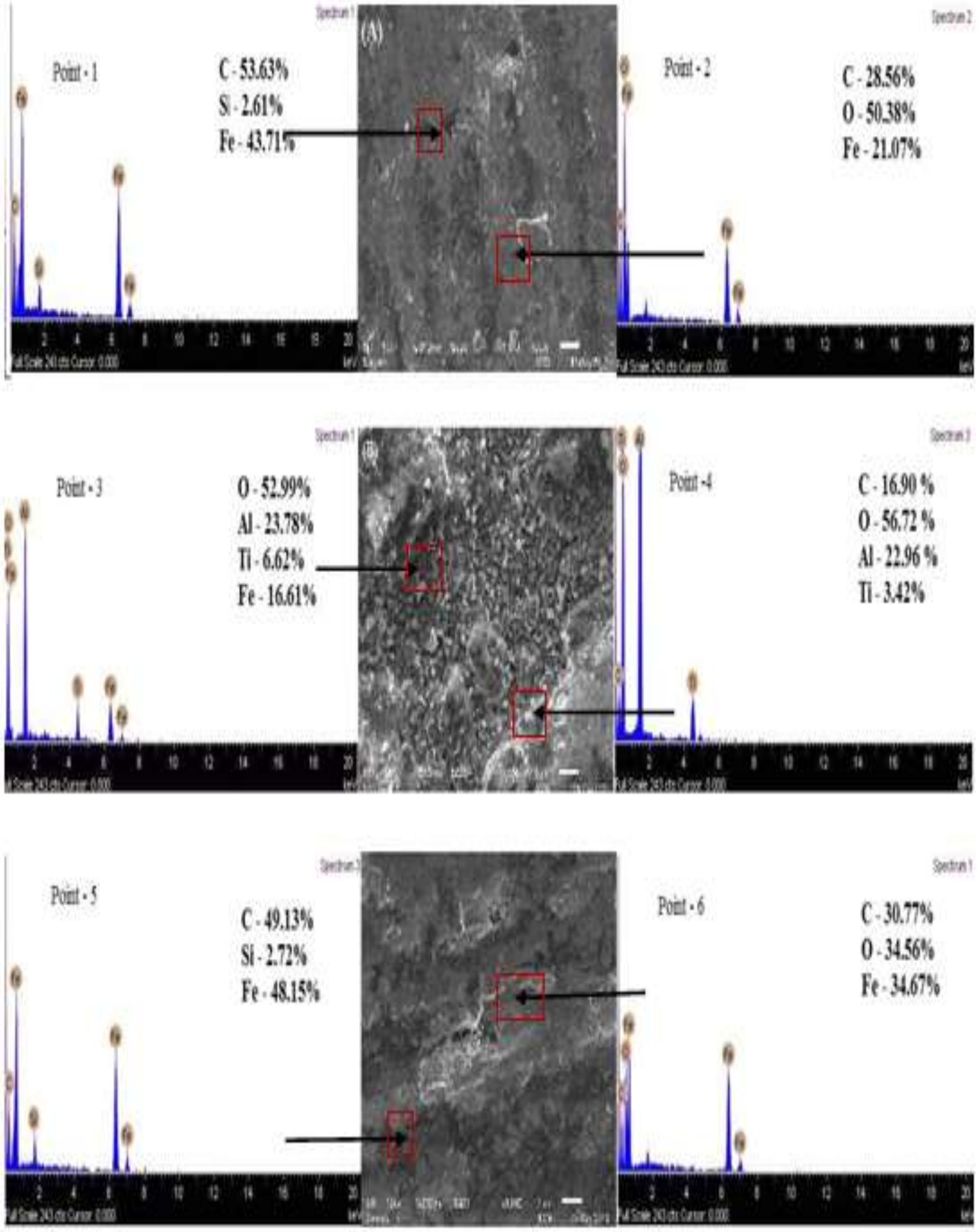

Figure 4: SEM micrographs and EDS spectrum with EDAX elemental composition of worn out sample for (a) Ni Cr (b) Al_2O_3 13 TiO_2 (c) Bare GIHC at 40 N

The SEM and EDAX analysis of the worn surfaces of (a) NiCr (b) Al_2O_3-$13TiO_2$ and (C) Bare GI250 substrate at normal load of 40N are shown in Figure 5. In general micrographs (in Figure 5) do not show any cracks on the surface. Figure 5(a) Point-1 shows the presence of Fe , C and O which makes it clear that the surface is worn out at this place and at point-2 the Ni and Cr is also present along with Fe and other components which indicates that surface lacks the presence of coating after wear. In Figure B at point-3 C is 41.95% and Fe (13.63%) which makes it clear that this surface is worn out at this point. But at point-2 the grey area identifies that the surface is not worn out. In Figure C point-5 shows high presnce of Fe and other components of Fe which proves the surface to be worn out and at point-6 Fe (40.59%) is present along with C (26.27%) and O (28.16%) which indicates that surface is higly worn out at this point.

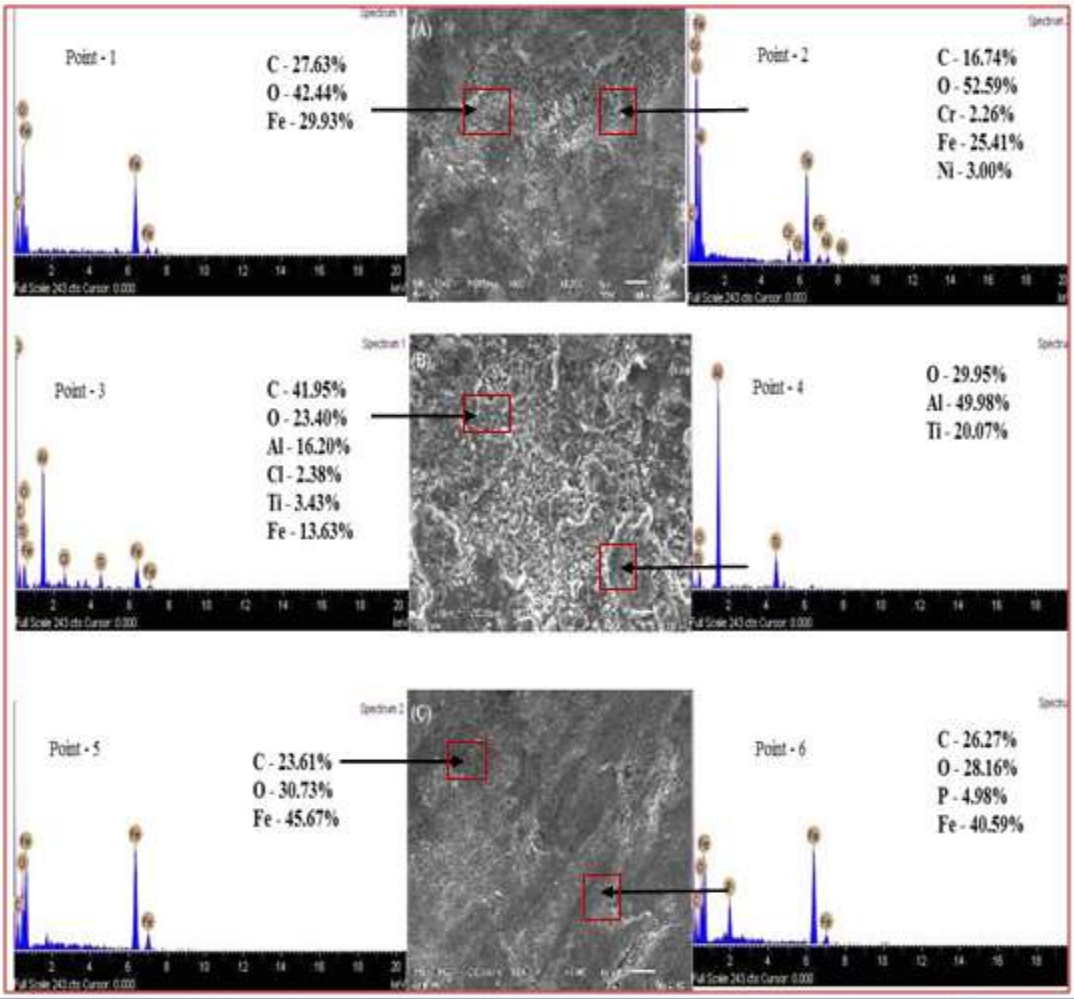

Figure 5: SEM micrographs and EDS spectrum with EDAX elemental composition of worn out sample for (a) Ni Cr (b) Al_2O_3 13 TiO_2 (c) Bare GI250 at 40 N

IV. Conclusion

Based upon experimental results obtained in the present work, the following conclusions have been drawn:

- Detonation Sprayed Ni20Cr, Al_2O_3-13TiO_2 coatings have successfully been deposited on GI250 and GIHC grades of grey cast iron.
- The detonation sprayed Ni20Cr, Al_2O_3-13TiO_2 coated GI250 and GIHC specimens showed significantly lower cumulative volume loss as compared to bare GI250 and GIHC materials.
- Cumulative Volume loss for detonation sprayed Ni20Cr, Al_2O_3-13TiO_2 coated as well as bare GI250 and GIHC specimens increases with increase in load.
- The Cumulative Volume loss for Al2O3-13TiO_2 coating was observed to be minimum in the present study.
- The Al2O3-13TiO_2-GI250 coating substrate combination has shown minimum Cumulative Volume loss among all the four combinations. The wear resistance for coating–substrate combinations in their decreasing order (at 40N) is Al_2O_3-13TiO_2 -GI250 > Ni20Cr-GI250 > $Al_2O_3$13TiO_2-GIHC > Ni20Cr-GIHC

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