TP 13791E

Comparison of the IRV and the IMAG on Winter Contaminated Surfaces

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16. Abstract

The proposed American Society for Testing and Materials standard for the International Runway Friction Index specifies a reference tester that is similar to the Instrument de Mesure Automatique de Glissance (IMAG). In January 2000 an International Reference Vehicle (IRV) was provided to the Joint Winter Runway Friction Measurement Program (JWRFMP) to serve as the standard reference. The purpose of the current study was to compare the data obtained from the IRV and the IMAG, the latter of which has participated in the JWRFMP since its inception in 1995.

In January 2000 tests were conducted with the IMAG and the IRV in North Bay, Ontario, Canada, and Munich, Germany. Measurements were taken by the two devices under the same winter surface conditions. It was found that there was a very high correlation between the IRV and the IMAG, and that the IRV produced results that were five percent lower than those produced by the IMAG. The recommended relationship for relating the friction measurements in winter conditions is: IRV = 0.95 IMAG

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16. Résumé

La norme proposée par l'American Society for Testing and Materials (ASTM) pour déterminer l'Indice international de la glissance des pistes prescrit l'utilisation d'un appareil de mesure de référence semblable à l'Instrument de mesure automatique de glissance (IMAG). En janvier 2000, un véhicule de mesure de référence (IRV, *International Reference Vehicle*) était fourni aux chercheurs du Programme conjoint de recherche sur la glissance des chaussées aéronautiques l'hiver (PCRGCAH) pour qu'ils s'en servent à titre d'appareil étalon. Cette étude visait à comparer les données recueillies à l'aide de l'IRV avec celles obtenues avec l'IMAG, qui a participé à toutes les études du PCRGCAH depuis les débuts de celui-ci en 1995.

Les essais ont eu lieu en janvier 2000 à North Bay, Ontario, au Canada, et à Munich, en Allemagne. Les mesures ont été prises avec les deux appareils sur des chaussées recouvertes des mêmes précipitations hivernales. Une très forte corrélation a été constatée entre les données de l'IRV et celles de l'IMAG. Les résultats obtenus avec l'IRV étaient de 5 p. cent inférieurs à ceux obtenus avec l'IMAG. Voici donc l'équation recommandée pour exprimer la relation entre les coefficients de frottement obtenus à l'aide des deux appareils, dans des conditions hivernales : IRV = 0,95 IMAG.

17. Mots clés: Indice international de la glissance des pistes, IRFI, véhicule de mesure de référence, IRV, Instrument de mesure automatique de glissance, IMAG

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EXECUTIVE SUMMARY

The proposed American Society for Testing and Materials standard for the International Runway Friction Index (IRFI) specifies a reference tester that is similar to the Instrument de Mesure Automatique de Glissance (IMAG). The objective of this study was to compare the IMAG and the International Reference Vehicle (IRV), which was provided to the Joint Winter Runway Friction Measurement Program to serve as the standard reference, and to establish the relationship between the data obtained from the two devices. This relationship is intended to be used to convert measurements made by the IMAG prior to January 2000 to the IRFI, which would have been determined by the IRV had it been available.

To determine this relationship, the IRV and the IMAG participated in 807 paired tests in North Bay, Ontario, Canada, from January 17 to 27, 2000, and in 134 paired tests in Munich, Germany, from February 21 to 26, 2000. Tests were conducted for a wide variety of winter surface conditions, including ice, compacted snow, slush, and bare pavement. Test speeds ranged from 30 to 90 km/h. The surface conditions provided a range of friction measurements from 0.05 to 0.91.

Considering the similarity of the IMAG and the IRV, a simple linear regression of the data was considered to be adequate to develop a relationship to relate the results of one to the results of the other. Based on a very large data set it was found that a high degree of correlation existed between the IRV and the IMAG. It was found that the IRV produced values for friction that were five percent lower than the IMAG on winter contaminated surfaces. In practice it would therefore be sufficient to multiply the value produced by the IMAG by 0.95 to predict the value expected from a measurement by the IRV. This result is applicable to friction measurements based on both friction force and braking torque.

Given that this study was limited to data on winter contaminated surfaces, it is recommended that the IRV and the IMAG be compared on wet pavement conditions and an analysis of the relationship between the IRV and the IMAG for wet pavement friction be presented in a separate report.

SOMMAIRE

La norme proposée par l'American Society for Testing and Materials (ASTM) pour déterminer l'Indice international de la glissance des pistes prescrit l'utilisation d'un appareil de mesure de référence semblable à l'Instrument de mesure automatique de glissance (IMAG). Cette étude visait d'abord à comparer les données recueillies à l'aide de l'IMAG avec celles obtenues avec le véhicule de mesure de référence (IRV, *International Reference Vehicle*) fourni aux chercheurs du Programme conjoint de recherche sur la glissance des chaussées aéronautiques l'hiver (PCRGCAH) en tant qu'appareil étalon, puis à définir la relation entre les données obtenues avec les deux appareils. Cette relation doit permettre d'utiliser les mesures prises par l'IMAG avant janvier 2000 pour déterminer l'IRFI que l'on aurait obtenu avec l'IRV, si ce dernier avait existé.

Pour définir cette relation, les chercheurs ont mené 807 essais jumelés avec l'IRV et l'IMAG à North Bay, Ontario, au Canada, du 17 au 27 janvier 2000, et 134 essais semblables à Munich, en Allemagne, du 21 au 26 février 2000, dans une vaste gamme d'états de chaussées (chaussées recouvertes de glace, de neige tassée, de neige fondante, chaussée dégagée). La vitesse des véhicules de mesure variait de 30 à 90 km/h et les coefficients de frottement résultants, de 0,05 à 0,91.

Compte tenu de la similarité entre l'IMAG et l'IRV, les chercheurs ont estimé suffisant de soumettre les données à une simple analyse de régression linéaire pour définir la relation entre les résultats d'un appareil et ceux de l'autre. Disposant d'un ensemble de données imposant, les chercheurs ont constaté un degré élevé de corrélation entre l'IRV et l'IMAG. Les valeurs de frottement obtenues avec l'IRV se sont révélées 5 p. cent inférieures à celles obtenues avec l'IMAG sur des chaussées contaminées par des précipitations hivernales. Dans la pratique, il suffirait donc de multiplier par 0,95 la valeur produite par l'IMAG pour extrapoler la valeur que l'on obtiendrait avec l'IRV. Ce résultat s'applique aux mesures de frottement dérivées autant de la force de frottement que du couple de freinage.

Comme cette étude portait exclusivement sur les données obtenues sur des surfaces contaminées par des précipitations hivernales, il est recommandé de réaliser des études comparatives de l'IRV et de l'IMAG sur des chaussées mouillées et que les résultats d'analyse de la relation entre les coefficients de frottement sur chaussées mouillées fasse l'objet d'un rapport distinct.

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1. OBJECTIVE

The objective of this study was to establish the relationship between the data obtained from the International Reference Vehicle (IRV), which was introduced in January 2000, and the Instrument de Mesure Automatique de Glissance (IMAG), which has participated in the Joint Winter Runway Friction Measurement Program (JWRFMP) since its inception in 1995.

2. INTRODUCTION

The *Service Techniques des Base Aériennes* (STBA) has participated in the JWRFMP since its inception in 1995, bringing an IMAG to the JWRFMP winter tests. The purpose of these winter tests is to develop a harmonized International Runway Friction Index (IRFI) that can be reported by any of various types of runway friction testers. To accomplish this harmonization a stable reference device is needed to establish the "true value" of the IRFI to which other systems can be calibrated.

In January 2000, STBA provided a device similar to the IMAG to be designated as the IRV, which would report the IRFI to which other devices would be calibrated. The version of American Society for Testing and Materials (ASTM) Standard E-2100-00[1] currently under consideration specifies this device as the reference for the IRFI. To be able to use the data from previous years, a relationship between the IMAG and the IRV was required. To determine this relationship, the IRV and the IMAG participated in 807 paired tests in North Bay, Ontario, Canada, from January 17 to 27, 2000, and in 134 paired tests in Munich, Germany, from February 21 to 26, 2000.

3. DATA

The IMAG and the IRV provide friction based on both force and torque measurements, and these were reported for each test. Tests were conducted for a wide variety of winter surface conditions, including ice, compacted snow, slush, and bare pavement. Conditions also included loose compacted snow, slush and bare pavement. Conditions also included loose snow cover up to about 5 mm in depth over ice, compacted snow, and bare pavement. Test

[1] *Standard Practice for Calculating the International Runway Friction Index*, ASTM Standard E-2100-00, Revision under Ballot, American Society for Testing and Materials, West Conshohocken, PA, October 2000.

speeds ranged from 30 to 90 km/h. The surface conditions provided a range of friction measurements from 0.05 to 0.91. Altogether, 941 runs were made with the IMAG and the IRV operating under similar conditions.

Some runs were made to study the effects of different test tires. The effects of excluding these 159 runs were considered in the analysis. In some cases the surfaces were extremely non-homogeneous, making it appear questionable that the two test vehicles were actually measuring the same surface condition.

4. ANALYSIS

Considering the similarity of the IMAG and the IRV, a simple linear regression of the data was considered to be adequate to develop a relationship to relate the results of one to the results of the other. In this case it was desired to predict what the IRV would have measured using a measurement made by the IMAG. If successful, the IMAG data from the years prior to 2000 could be used to estimate what the IRV would have reported had it been present.

The regressions are of the form:

$$\text{IRV} = a\ \text{IMAG} + b \qquad (1)$$

where IRV is the friction value reported by the IRV and IMAG is the friction value reported by the IMAG under the same conditions. *a* and *b* are regression coefficients.

Figure 1 shows the results for North Bay (807 runs) for friction determined from friction force measurements and Figure 2 shows the corresponding results for Munich (134 runs)[2] with the correlation coefficient (R^2).

For North Bay:	IRV = 0.887 IMAG + 0.010	R^2 = 0.882	(2)
For Munich:	IRV = 0.908 IMAG + 0.004	R^2 = 0.823	(3)

Because the results were sufficiently similar, the data were combined for the two locations and the result is shown in Figure 3.

[2]Note that in these figures and those that follow, the number of points shown appears to be fewer than the number of the data. Because many of the data are close, a point on the figure may represent multiple data.

Combined force data:

$$IRV = 0.885\ IMAG + 0.010 \quad R^2 = 0.878 \qquad (4)$$

Figures 4 and 5 show the results for North Bay and Munich for friction determined from braking torque measurements.

For North Bay: $IRV = 0.885\ IMAG + 0.006 \quad R^2 = 0.870 \qquad (5)$

For Munich: $IRV = 0.897\ IMAG + 0.025 \quad R^2 = 0.775 \qquad (6)$

Again, because the results were sufficiently similar, the data for the two locations were combined as shown in Figure 6.

Combined torque data:

$$IRV = 0.894\ IMAG + 0.007 \quad R^2 = 0.851 \qquad (7)$$

Comparison of equations 4 and 7 suggests that the relationship between the IRV and the IMAG is the same for force- and torque-based measurements. Figure 7 shows the results of combining all force and torque data (1882 points).

All data: $IRV = 0.890\ IMAG + 0.008 \quad R^2 = 0.881 \qquad (8)$

When tests were run with different tires on the IMAG and IRV, the results did not change significantly:

All data except tire studies (1564 points):

$$IRV = 0.881\ IMAG + 0.013 \quad R^2 = 0.884 \qquad (9)$$

Examination of the figures showed that there were some outliers in the data where the IRV was both above and below the line of regression. This must be attributed in part to the fact that some of the surfaces were extremely non-uniform across the test bed. Therefore, in these cases it is likely that the data that is evenly distributed above and below the regression line. Arbitrarily removing the outliers (those points that are more than 0.05 from the regression line) and eliminating the runs with different tires produced the results shown in Figure 8 (1513 data points).

All data outliers removed:

$$IRV = 0.948\ IMAG + 0.001 \qquad R^2 = 0.919 \qquad (10)$$

Noting that the intercept *b* is quite small (only 0.001), the following relationship can be considered:

$$IRV = 0.95\ IMAG \qquad (11)$$

Although equation 11 appears to be quite different from equations 8 and 9, in practice the difference in friction values is quite small when the friction values are below 0.50. The difference in using equation 8, 9 or 11 is unimportant because maintenance decisions are made when the friction is below 0.50. The comparison of equation 11 and equation 8 is shown in Figure 7 where all the data are also shown.

5. RECOMMENDATIONS AND CONCLUSIONS

It is recommended that equation 11 be used to estimate a measurement that the IRV would produce from a measurement made by the IMAG.

Based on a very large data set, it was found that a high degree of correlation exists between the IRV and the IMAG. It was found that the IRV produces values for friction that are five percent lower than the IMAG on winter contaminated surfaces. In practice, it is sufficient to multiply the value produced by the IMAG by 0.95 to predict the value expected from a measurement by the IRV. This result is applicable to friction measurements based on both friction force and braking torque.

Given that this study was limited to data on winter contaminated surfaces, it is recommended that the IRV and the IMAG be compared on wet pavement conditions and an analysis of the relationship between the IRV and the IMAG for wet pavement friction be presented in a separate report.

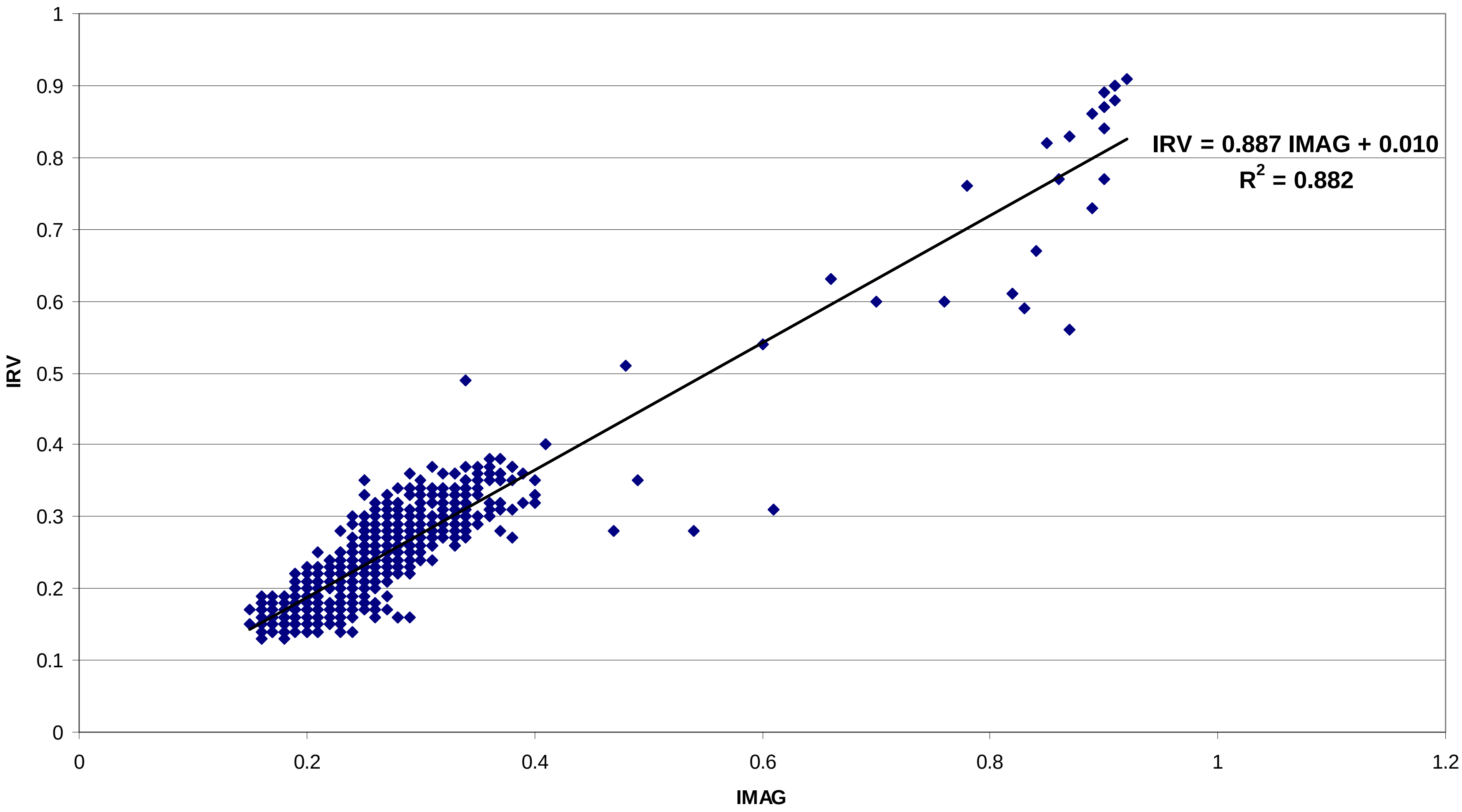

Figure 1   IRV vs. IMAG - Force Measurements at North Bay

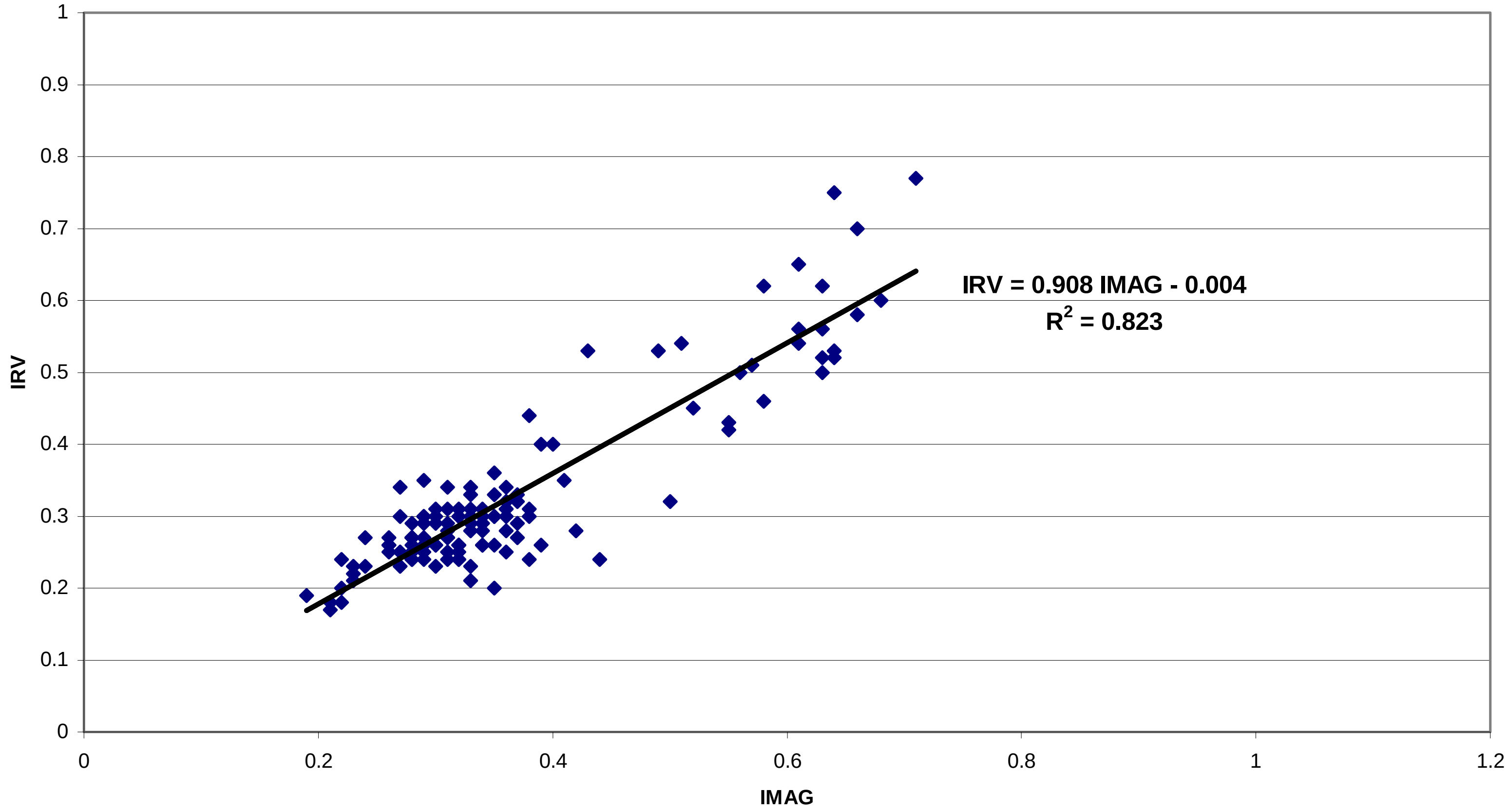

Figure 2 IRV vs. IMAG - Force Measurements at Munich

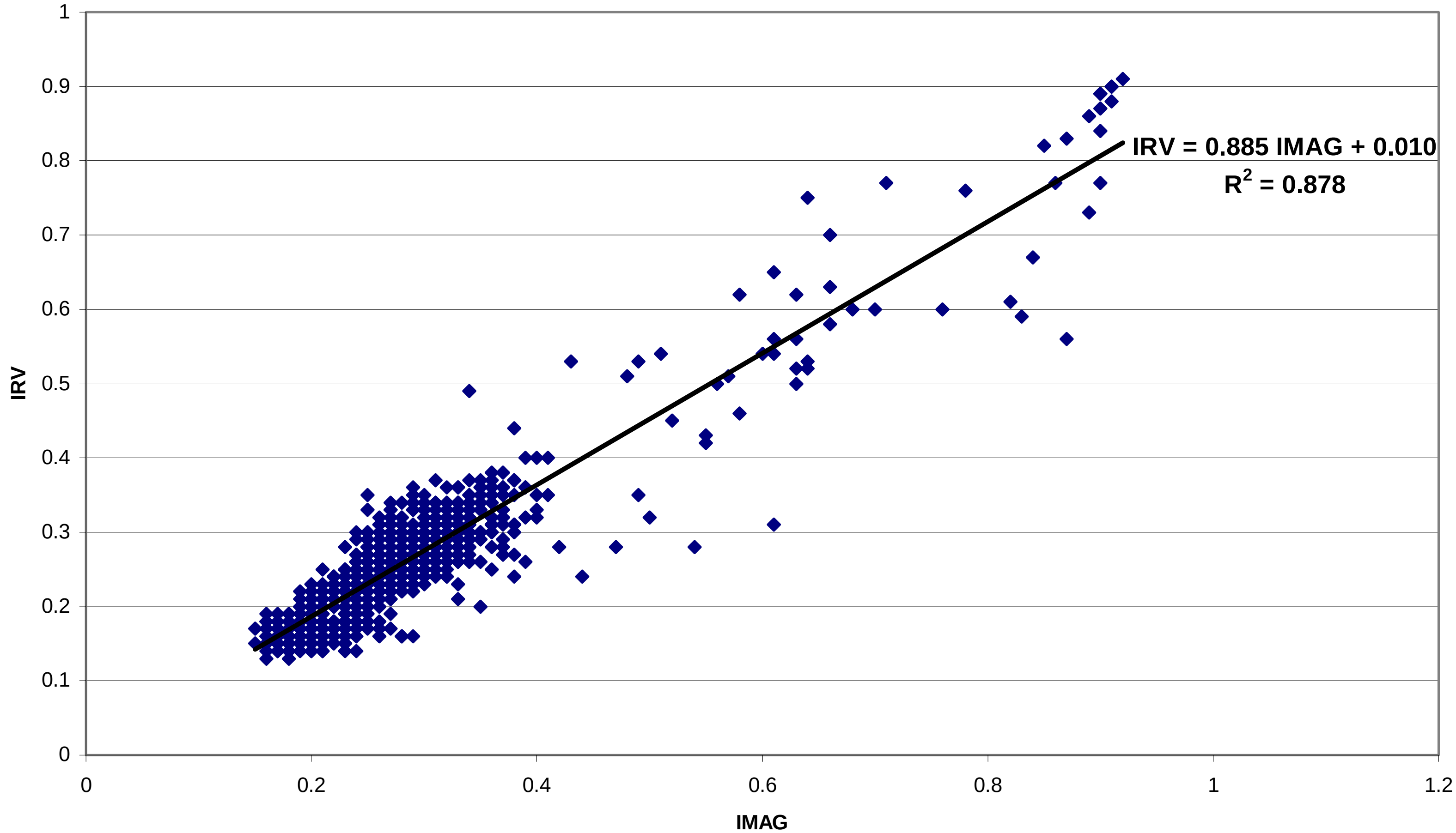

Figure 3 IRV vs. IMAG - All Force Measurements in 2000

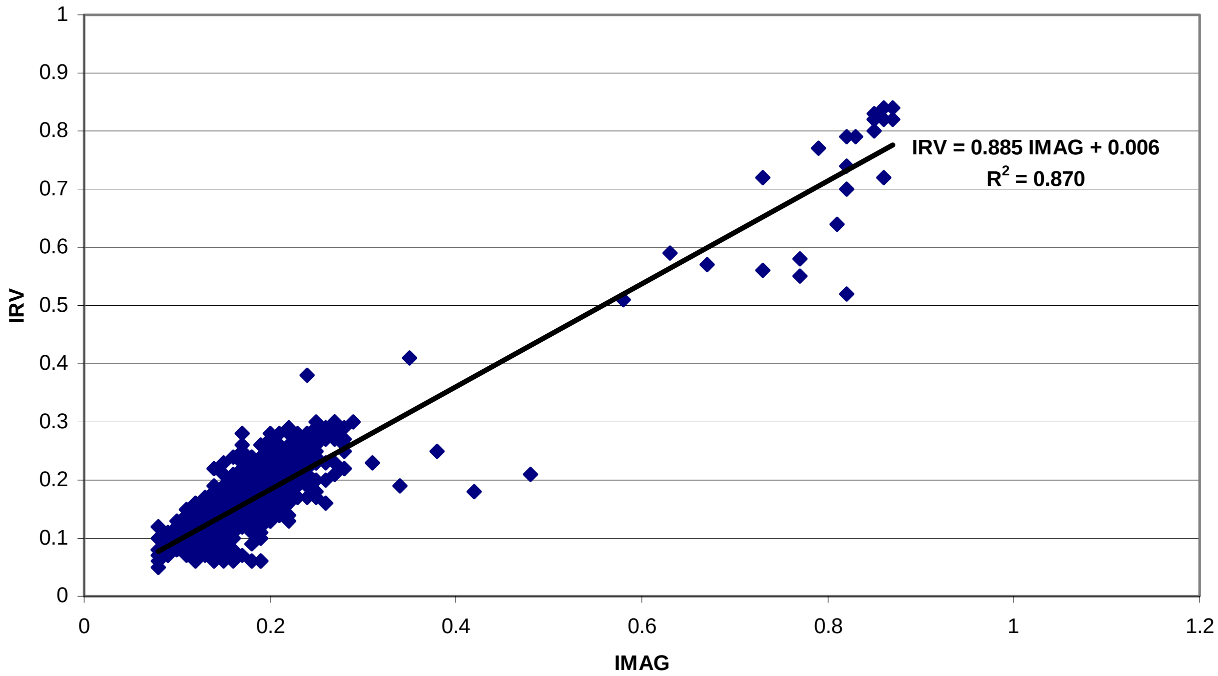

Figure 4   IRV vs. IMAG - Torque Measurements at North Bay

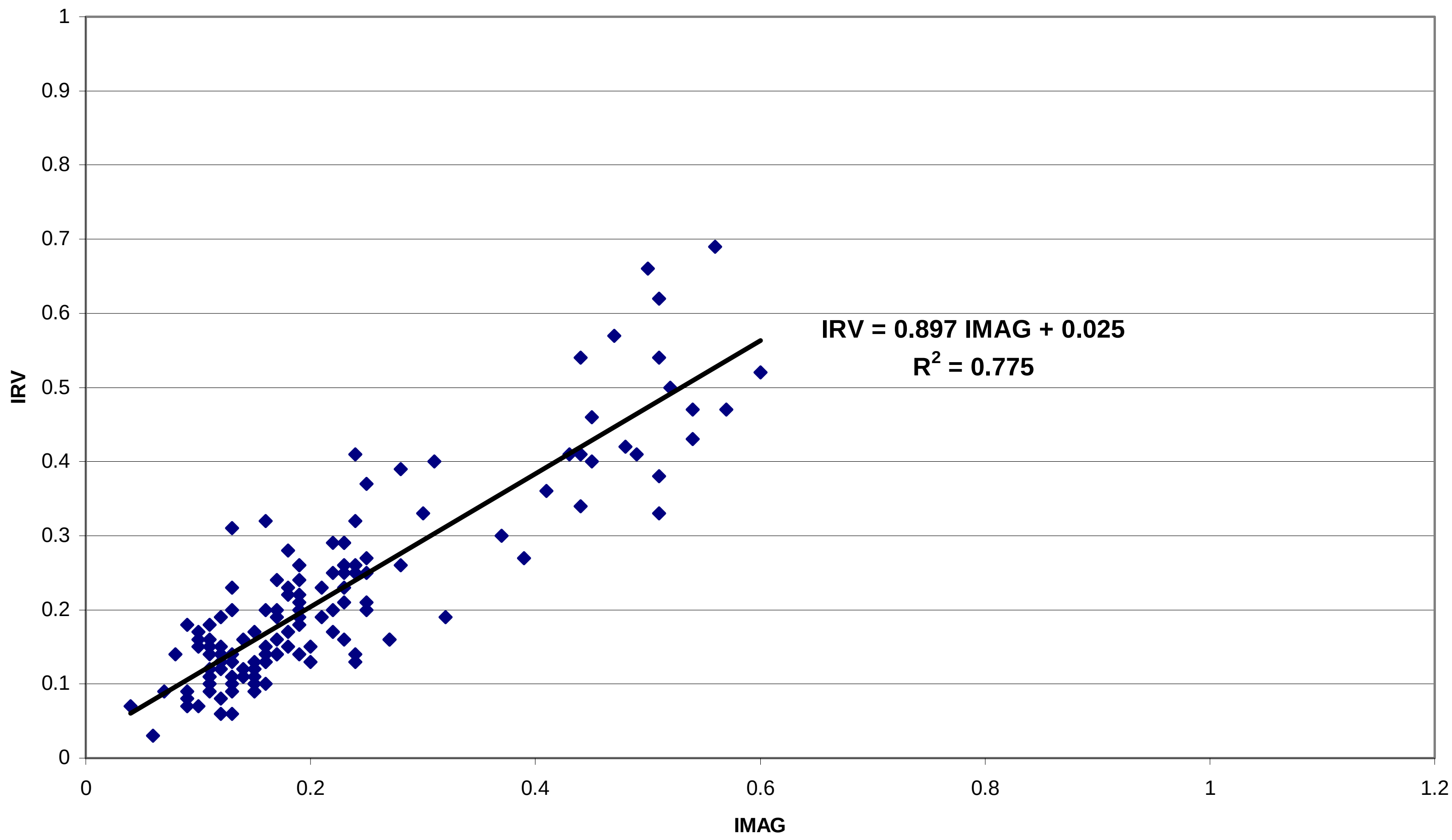

Figure 5 IRV vs. IMAG - Torque Measurements at Munich

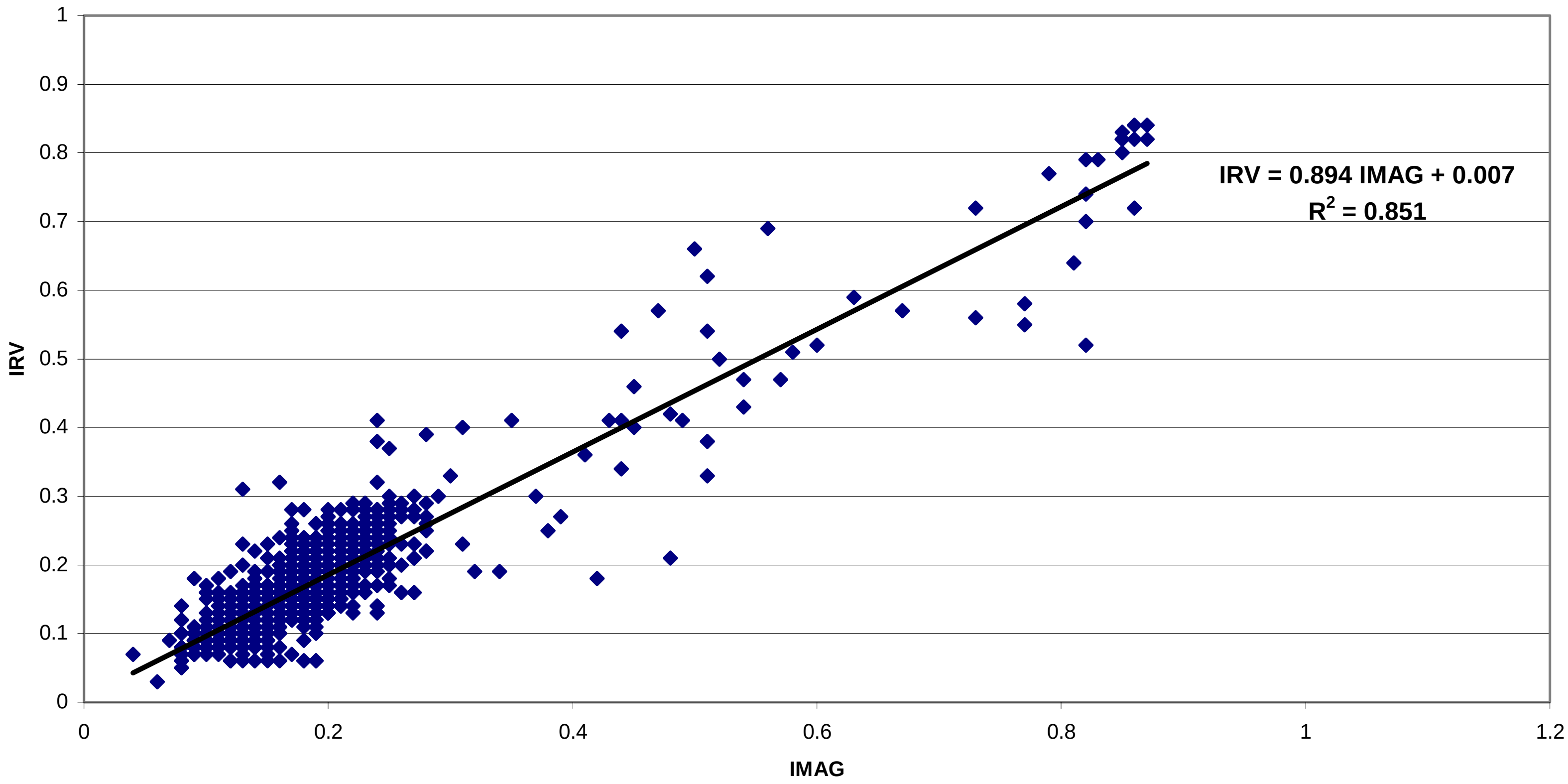

Figure 6 IRV vs. IMAG - All Torque Measurements in 2000

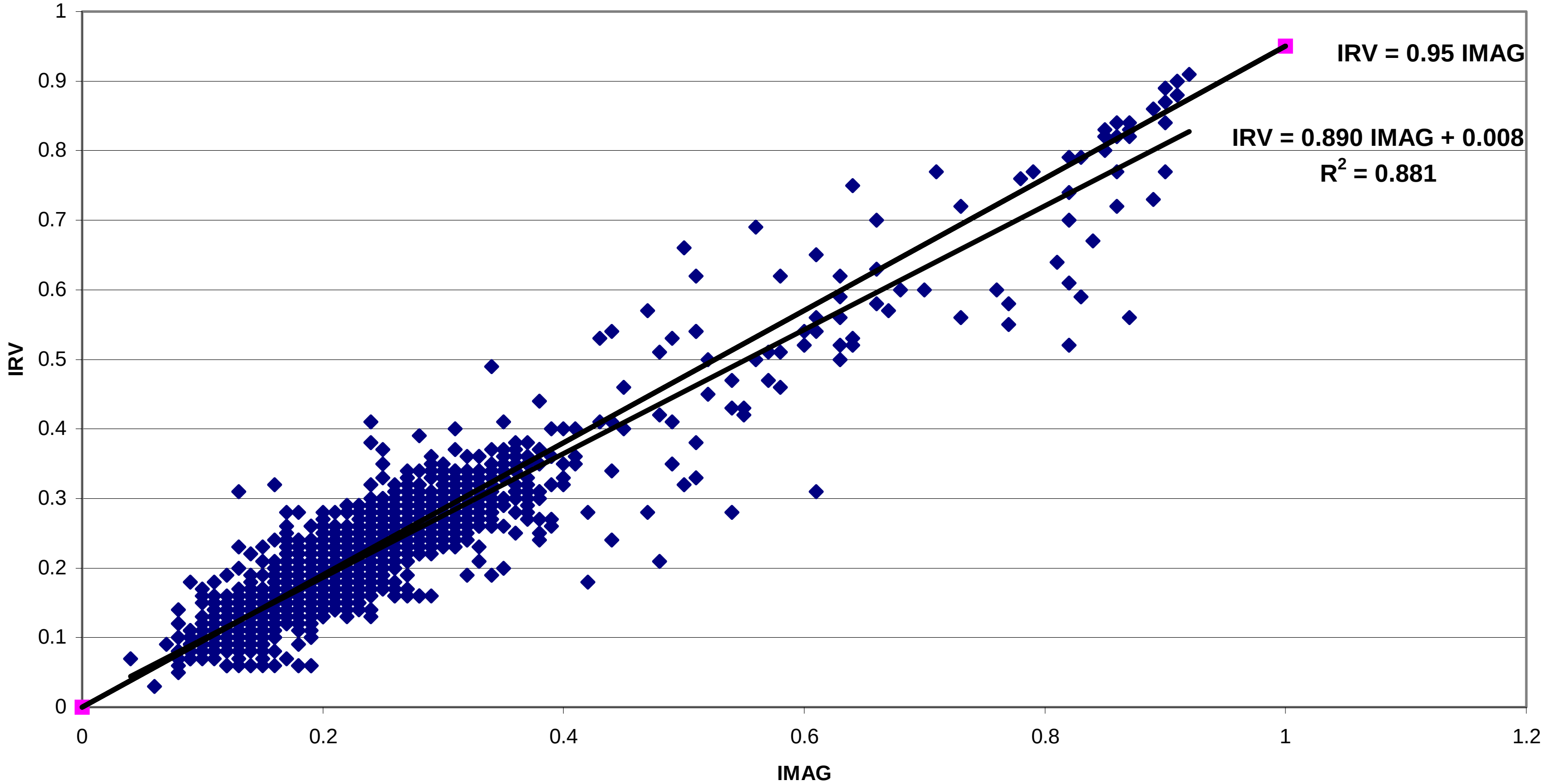

Figure 7 IRV vs. IMAG - All Force and Torque Measurements in 2000

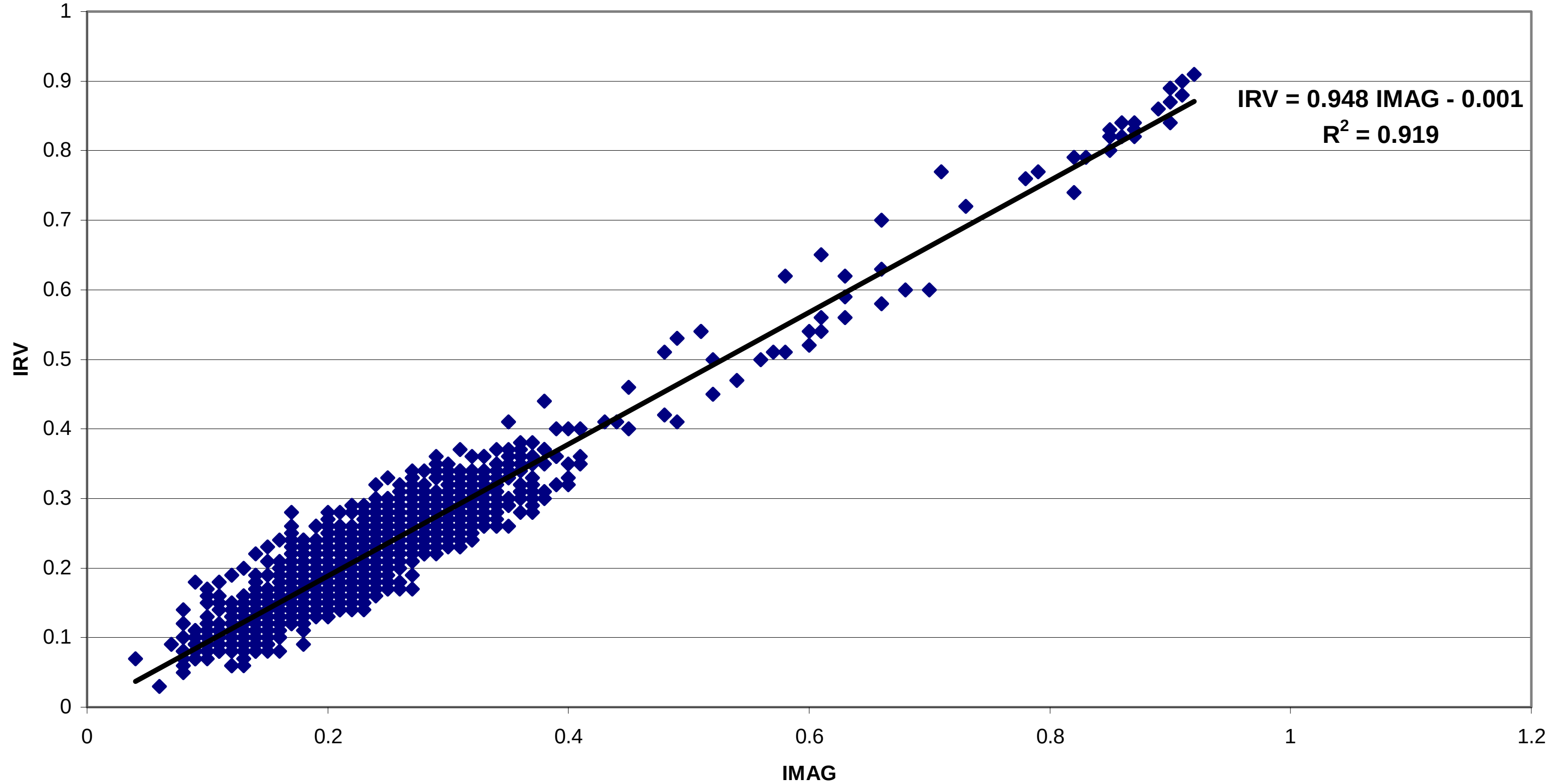

Figure 8 IRV vs. IMAG - Force and Torque Measurements (Outliers Removed)