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Airfoils with high lift-drag ratio at a Reynolds number of about one million

by

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There seems to be a growing interest in a special type of aircraft which can stay in the air at the lowest expenditure of energy, i.e. at the lowest possible sinking speed. Obviously such aircraft need airfoils with high lift-drag ratios. To be more exact, it is the ratio $c_L^{1.5}/c_D$ which should attain the highest possible values. In the following, two airfoils are described which, as a first approach, fill the gap of suitable airfoil data.

Before designing such airfoils some short remarks may be necessary. In the ratio $c_L^{1.5}/c_D$ the lift has more weight than the drag. Therefore the desired airfoil will have in all cases an unusually high degree of camber. On the other hand, when the aircraft has to "float" only on straight courses or wide circles, the optimum aspect ratio will also be high and structural strength and stiffness call for a thick airfoil. In my previous paper [1] I have mentioned that the combination "thick and cambered" poses a serious difficulty for the boundary layer on the upper side. The situation is aggravated by the low Reynolds number as one would expect for such a slow and/or high flying machine.

In order to reduce the risk, two airfoils with a medium thickness of 15% were designed which differ only in the degree of camber. Fig.1 shows the geometry of the two airfoils, A with 8,3% and B with 9,7% camber.

The experimental results are represented in Figs.2 and 3 *). It can be seen that both airfoils have maximum glide ratios of about 160 at high c_L-values. The sinking speed ratio $c_L^{1.5}/c_D$ of these two and some other airfoils [2] is evaluated for a Rey-

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*) These measurements were again performed by Dipl.Phys.D.Althaus

nolds number of one million in Fig.4. Fig.5 exhibits the influence of different Reynolds numbers. The less cambered airfoil 150 A has a single peak of $c_L^{1.5}/c_D$ over 200, whereas the 150 B reaches the value 180 in a much more extended range of c_L. Both new airfoils exceed the VC-170/136 airfoil which has only 11,4% thickness, as well as the FX 63-137 which was designed for man powered aircraft. The fact that the new airfoils attain the maximum values of $c_L^{1.5}/c_D$ at higher lift values than any previous airfoils seems to be especially attractive when the flight mechanics of an airplane are taken into account: usually high aspect ratios, which might be easily attainable with future fibre technology, call for high c_L-values and this is even more true when the sinking speed should be minimized in circling flight.

1 F.X.Wortmann, "A critical review of the physical aspects of airfoil design at low Mach numbers"
MIT Symposium 1972 "Technology and Science of Motorless Flight", Cambridge/Mass.

2 D.Althaus, "Stuttgarter Profilkatalog I"
MIT Symposium 1972 "Technology and Science of Motorless Flight", Cambridge/Mass.

Table 1.

No.	$\frac{x}{c}$	FX 72-MS-150A $\left(\frac{y}{c}\right)_u$	 $\left(\frac{y}{c}\right)_l$	FX 72-MS-150B $\left(\frac{y}{c}\right)_u$	 $\left(\frac{y}{c}\right)_l$
2	.99893	.00037	.00034	.00041	.00042
4	.99039	.00331	.00236	.00368	.00296
6	.97347	.00914	.00617	.01017	.00767
8	.94844	.01775	.01160	.01977	.01430
10	.91573	.02901	.01793	.03230	.02210
12	.87592	.04272	.02437	.04756	.03022
13	.85355	.05042	.02735	.05614	.03408
14	.82967	.05864	.03005	.06529	.03768
15	.80438	.06735	.03223	.07498	.04074
16	.77779	.07651	.03391	.08518	.04330
17	.75000	.08607	.03487	.09583	.04507
18	.72114	.09517	.03522	.10572	.04619
19	.69134	.10425	.03473	.11554	.04639
20	.66072	.11294	.03363	.12487	.04591
21	.62941	.12137	.03170	.13387	.04449
22	.59755	.12916	.02924	.14213	.04245
23	.56526	.13631	.02609	.14964	.03962
24	.53270	.14247	.02266	.15605	.03640
25	.50000	.14781	.01881	.16155	.03266
26	.46730	.15175	.01506	.16553	.02892
27	.43474	.15444	.01090	.16813	.02463
28	.40245	.15510	.00741	.16858	.02092
29	.37059	.15434	.00423	.16753	.01742
30	.33928	.15171	.00171	.16449	.01449
31	.30866	.14813	-.00072	.16046	.01158
32	.27886	.14325	-.00277	.15503	.00897
33	.25000	.13753	-.00480	.14872	.00626
34	.22221	.13084	-.00659	.14137	.00377
35	.19562	.12339	-.00826	.13321	.00132
36	.17033	.11528	-.00975	.12433	-.00098
37	.14645	.10657	-.01113	.11484	-.00324
38	.12408	.09733	-.01231	.10474	-.00527
39	.10332	.08773	-.01328	.09430	-.00716
40	.08427	.07785	-.01407	.08352	-.00886
41	.06699	.06777	-.01461	.07256	-.01030
42	.05156	.05767	-.01485	.06154	-.01138
43	.03806	.04769	-.01486	.05072	-.01227
44	.02653	.03791	-.01432	.04007	-.01243
45	.01704	.02867	-.01380	.03050	-.01234
46	.00961	.01985	-.01246	.02150	-.01150
47	.00428	.01252	-.01056	.01330	-.00950
48	.00107	.00679	-.00596	.00650	-.00560

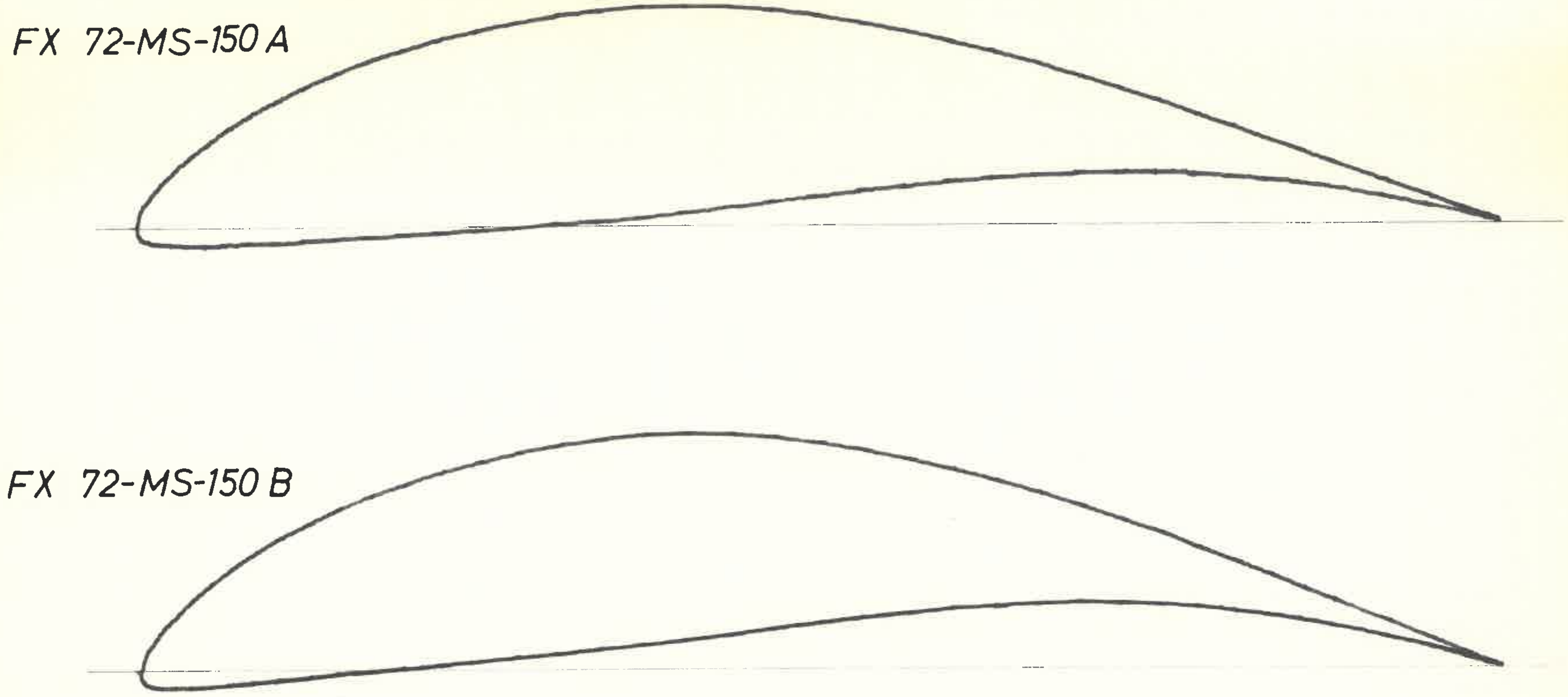

Fig.1 Two airfoils for low sinking speeds

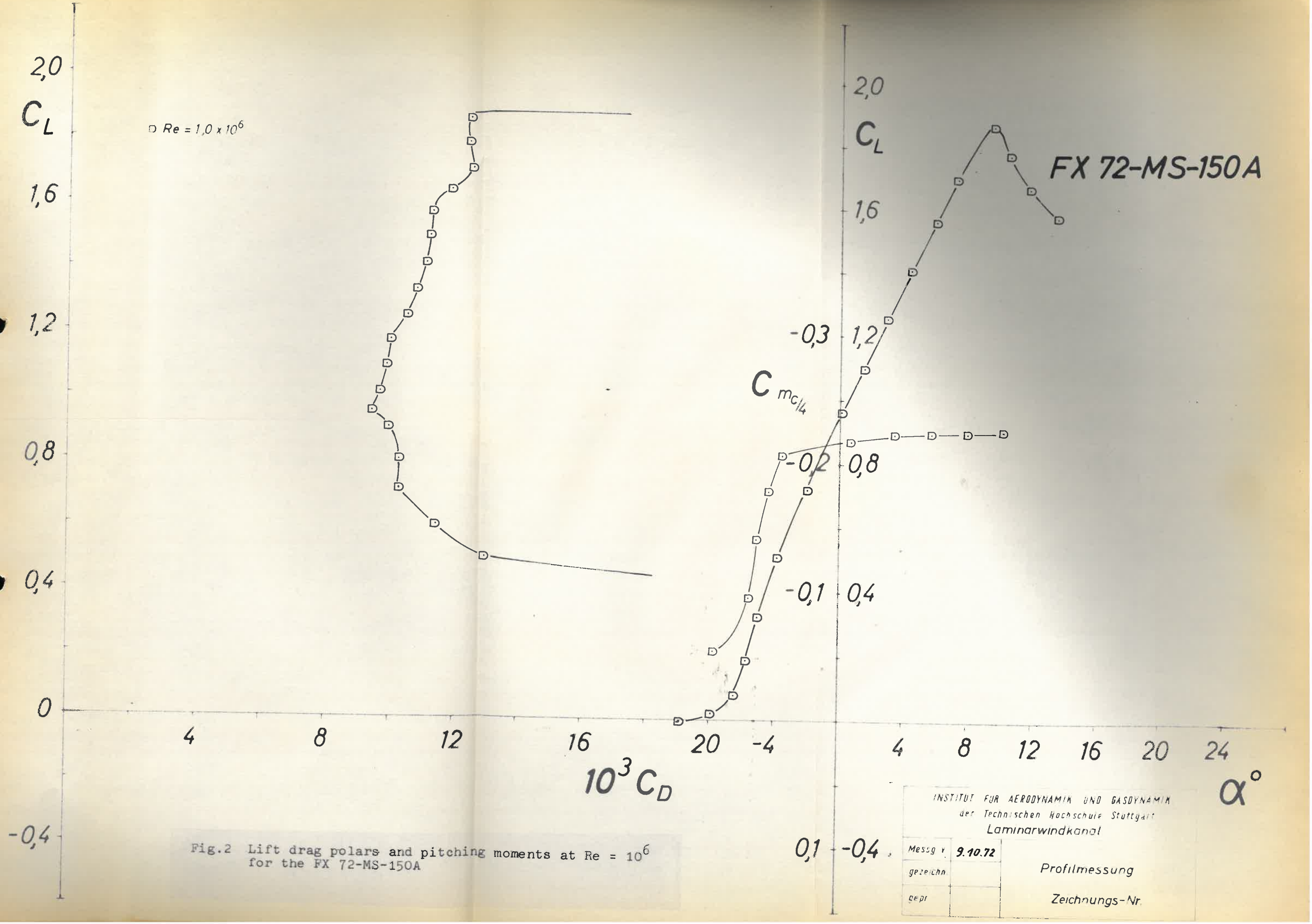

Fig.2 Lift drag polars and pitching moments at Re = 10^6 for the FX 72-MS-150A

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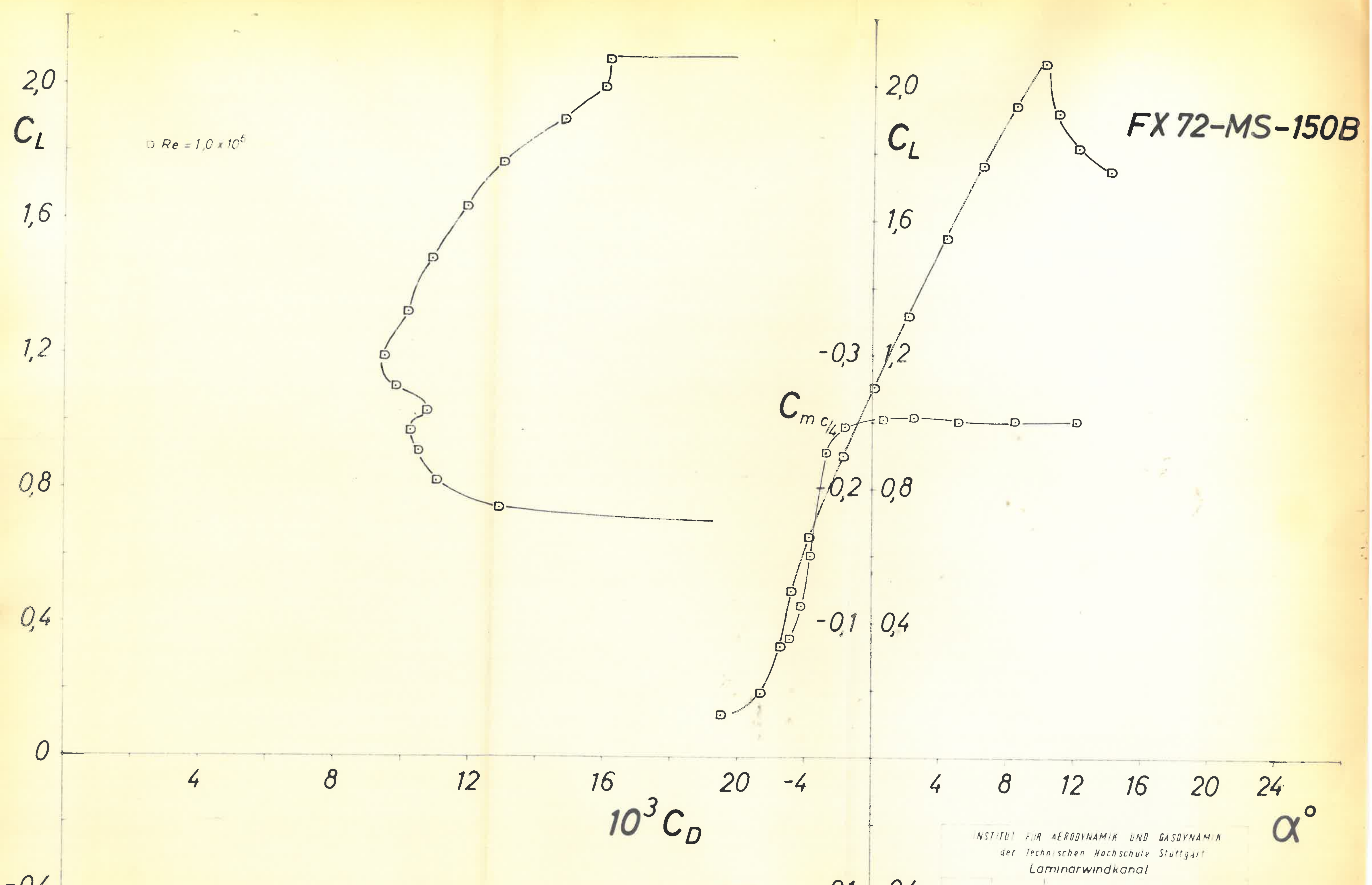

Fig.3 Lift drag polars and pitching moments at Re = 10^6 for the FX 72-MS-150B

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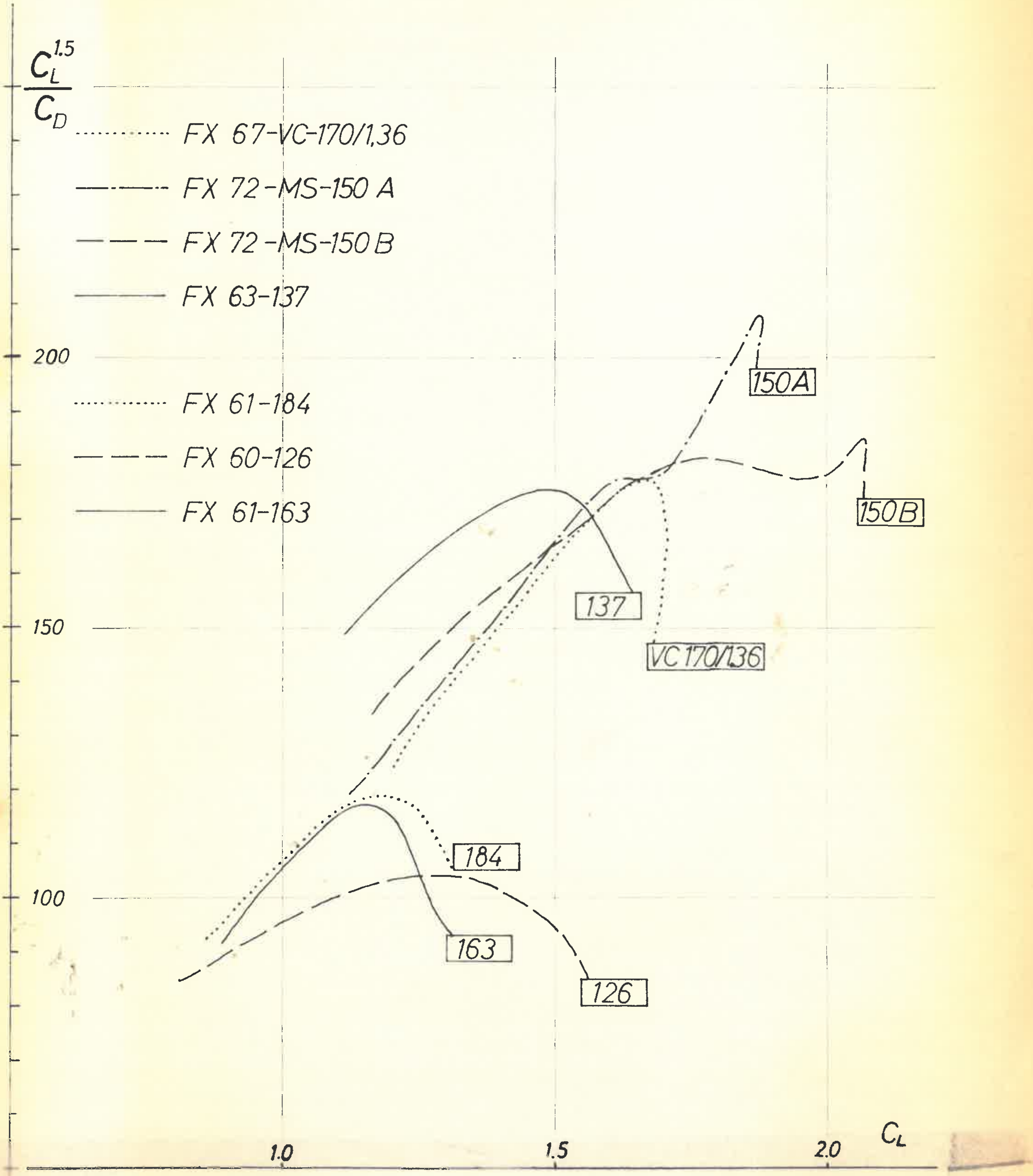

Fig.4 The value $c_L^{1.5}/c_D$ for different airfoils at $Re = 10^6$

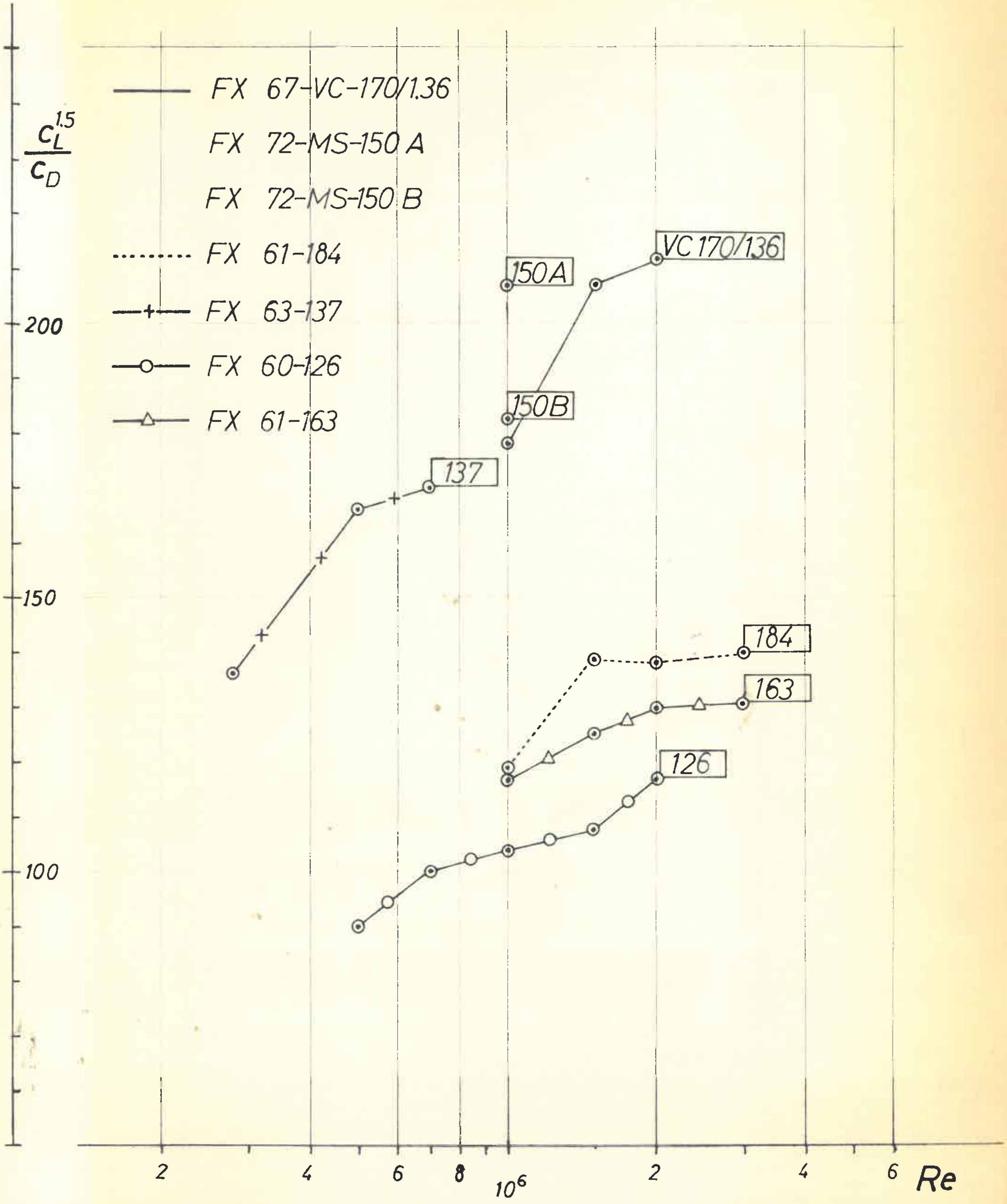

Fig.5 The influence of Reynolds number on the sinking speed parameter $c_L^{1.5}/c_D$