Introduction A lubricant provides a protective film which allows for two touching surfaces to be separated, thus lessening the friction between them. Lubricating oil is a liquid lubricant that reduces friction, protects against corrosion, reduce electric currents and cool machinery temperature. It is most often used in the automobile industry and is applied to bearings, dies, chains, cables, spindles, pumps, rails and gears to make them run smoother and more reliably. Lubricating oil is a substance introduced between two moving surfaces to reduce the friction and wear between them. Lubricating oils consist of a liquid paraffinic or vegetable oil and surface active agents, antioxidants and anticorrosive additives. Metal soaps in pure form or dispersed in paraffinic oils are used as lubricants. Felder et al [1] used sodium and calcium soap coatings on steel wires for drawing the wires. Calcium stearate had good lubricating efficiency at low wire drawing rates [1]. The possibility for the production of a motor oil with improved operating characteristics and a higher stability by applying of composite additives has been studied by Palichev et al [2]. For this purpose two multifunctional additives, synthesized by them have been used. They used additives containing calcium stearate and calcium salts of nitrated polypropylene and oxidized paraffin, urea, ethylene diammine, stearic acid. The additives improved the anticorrosion, viscosity-temperature, antiwear and antisludge properties of the lubricant [2]. The optimum concentration of the additive, which enables the production of a high-quality motor lubricant, has been found to be 5% [2]. Cutting oils were obtained by adding CaSt2 to dry paraffin oil up to 5 % together with other additives [3]. Thus the gelation was prevented and an easily flowing cutting oil was obtained. Savrik et al [4] prepared lubricants using base oil, surface active agent Span 60 and zinc borate particles. They used 1% Span 60 and 1 % zinc borate. Surface active agent Span 60 was found to be very effective in reducing the friction coefficient and wear scar diameter in four ball tests. As surface active agents metal soaps are also used. Metal soaps are transition metal salts of the fatty acids and the alkaline earth elements. Although, the alkali salts of the fatty acids such as sodium and potassium are water soluble, metal soap is water insoluble but more soluble in non-polar organic solvents. Calcium stearate Ca (C17H35COO)2, in short form CaSt2is the one of the important ionic surfactants of metal soaps. Calcium Stearate, is a non-toxic, white powdery substance. It is a calcium salt derived from stearic acid and is widely used in cosmetics, plastics, pharmaceuticals and lubricants [5]. Metal soaps can be obtained by neutralization of long chain organic acids with bases or by precipitation process. Moreria et al [6] investigated formation of CaSt2 from stearic acid and calcium hydroxide in different solvents and a complete conversion to CaSt2 was obtained in ethanol medium [6]. The precipitation process generally produces metal soap in powder form by the reaction of aqueous solutions of a water soluble metal salt and a fatty acid alkali metal salt at a temperature below the boiling point of water at atmospheric pressure. Filtering, washing, drying are the important steps in this method. Calcium stearate is produced in pure form by using this process [5]. Production of a lubricant by using a neutral base oil and calcium stearate is the aim of this study. The lubricating effects were tested by a four ball tester for this purpose. MATERIALS AND THE METHOD Materials Calcium chloride, $CaCl_2 \cdot 2H_2O$ (98%, Aldrich),and sodium stearate, (NaSt) $C_{17}H_{35}COONa$ (commercialproduct, Dalan Kimya A.S¸ ., Turkey), were used in the synthesis of $CaSt_2$. The acid value of stearic acid, used in the NaSt synthesis, was 208.2 mg of KOH/g of stearic acid and it consists of a C16-C18 alkyl chain and with 47.7% and 52.3% by weight, respectively[5]. Spindle Oil from TUPRAS Izmir was used as base oil in the preparation of the lubricants. Preparation of calcium stearate powder Calcium steatrate powder was prepared from sodium stearate and calcium chloride by precipitation from aqueous solutions according to reaction 1. $2C_{17}H_{35}COO^- + Na(aq) + Ca^{2+}(aq)$¾® $(C_{17}H_{35}COO)_2Ca(s) + 2Na^+ (aq)$ (1) 5.000 g (0.016 mol) of sodium stearate, (NaSt) was dissolved in 200 $cm^3$of deionized water in a stainless steel reactor at 75°C. 1.7984 g (0.012 mol) of calcium chloride (50% excess) was dissolved in 100 $cm^3$of deionized water at 30°C and added to sodium soap solution at 75oC. The mixture was stirred at a rate of 500 rpm at 75°C by a mechanical stirrer for 30 min. Since the by-product, NaCl, is soluble in water the reaction media was filtered by using Büchner funnel and flask under 600-mmHg vacuum level. To remove the NaCl completely, wet $CaSt_2$ was washed by 200 $cm^3$deionized water once and then, wet $CaSt_2$ cake was dried in a vacuum oven under 2x10 4 Pa pressure. The KBr disc spectrum of the powder was taken with Shimadzu FTIR spectrophotometer. The SEM micrograph of the dried powder was taken withScanning electron microscopy (Philips XL30 SFEG). Lubricant preparation 1g of $CaSt_2$ and 100 $cm^3$spindle oil were mixed together at 160 oC at 880 revolution $min^{-1}$ rate for 30 minutes and then cooled to 25oC by continuously stirring. At the mixing experiments, a heater and magnetic stirrer (Ika Rh Digital KT/C) and a thermocouple (IKAWerke) were used. The experiment was repeated with 2 g of $CaSt_2$ in 100 $cm^3$ oil. Lubricant characterization The dispersion of $CaSt_2$ in base oil was observed by optical microscopy. The phase change behavior of of $CaSt_2$ and lubricants with increasing temperature was observed with an optical microscope equipped with a hot plate. The stabilities of the lubricants having different calcium stearate contents were determined by measuring the rate of settling of calcium stearate particles in base oils. The chemical structures of calcium stearate and the prepared lubricants were investigated by FTIR spectroscopy. The tribologic behavior of the lubricants was tested with a four ball tester. Four ball tests were done using the four ball tester from DUCOM Corporation (Fig. 1) to determine the friction coefficient and wear scar diameter of the lubricants. The test was performed according to ASTM D 4172-94 at 392 N and 1200 rpm and the test duration was 1 h. The wear scar diameter was reported as the average of the wear scar diameter of the three fixed balls. Fig. 1 - Four ball tester The visible spectrum of base oil separated by centrifugation from base oil was taken by using Perkin Elmer UV-Vis spectrophotometer by using base oil without any additive as the reference. Optical microscope Melting behavior of $CaSt_2$ in powder form and in dispersed form in the base oil on a microscope slide was observed by using the transmission optical microscope (Olympus, CH40) with a heated hot stage controlled by a temperature controller (Instec, STC 200C). The samples were heated at 5oC/min rate from room temperature up to 190oC. The photographs were taken with Camedia Master Olympus Digital camera. Results and discussion CaSt2 powders FTIR spectrum of calcium stearate powder obtained by precipitation process is shown in Fig. 2. The characteristic peaks of calcium stearate at 1542 cm-1 and 1575 cm-1 were observed. These bands are due to antisymmetric stretching bands for unidendate and bidendate association of carboxylate groups with calcium ions [5, 7]. Antisymmetric and symmetric methylene stretching, and methylene scissoring bands (naCH2, nsCH2, and dsCH2) were observed at about 2914 cm-1, 2850 cm-1and 1472 cm-1 respectively. These bands are due to the alkyl chain in the calcium stearate structure [5, 7]. Fig. 2 - FTIR spectrum of bulk CaSt2 Fig. 3 - SEM micrograph of CaSt2 powder The SEM micrograph of the CaSt2 powder shown in Fig. 3 indicated that the particles were flat in in shape and had a broad size distribution ranging from 200 nm to 1µm. The average diameter of particles was 600 nm. FTIR spectra of lubricants The prepared lubricants were also examined by FTIR spectroscopy. Their FTIR spectra are shown in Figure 4. The peaks at 2918 and 2848 cm-1, 1454cm-1are due to stretching and bending vibrations of the methylene groups in base oil structure. The stretching and bending vibrations of the methyl group are observed at 2951 and 1385 cm-1. At 3414 cm-1 a broad peak related to hydrogen bonded OH groups are present. The antisymmetric stretching bands for unidendate and bidendate association of carboxylate groups with calcium ions at 1542 cm-1 and 1575 cm-1 are observed as small peaks in the spectra. Fig. 4 - FTIR spectra oflubricants with a - 1% CaSt2 b - 2% CaSt2 Stability of lubricants and the particle size of the CaSt2 dispersed in base oil The stability of the lubricant suspensions was determined by recording the height of the line separating the oil phase and the suspension phase. Due to gravity settling of the particles the level of this line decreases continuously with time as seen in Fig. 5.The settling velocity is directly proportional to the radius of the particle as shown in Equation 2[8]. dx/dt =2r2(ρ-ρo) g/9η (2) Where; dx/dt is rate of settling (cm/s); ρo is the density of medium (g/cm3), ρ is the density of particle (g/cm3), η is viscosity of medium (g/(cm.s)), r is radius of particle (cm), g is 981 cm/s2. The radius of particles was calculated from the slopes of the lines in Figure 6. The results were evaluated for the settling of particles within 15 days. The oil density and viscosity used for the calculations are 0.86 g/cm3 and 0.35 ((g/cm.s)). The density of CaSt2 is 1.12 g/cm3. The initial rate of settling was calculated as 0.188x10-7 cm/s and 0.635x10-12cm/s for oils with 1 % and 2 % CaSt2respectively from Fig. 6. Apparent radius of the CaSt2 particles dispersed in base oil was 1.88 µm and 0.11 µm respectively for 1 % and 2 % CaSt2 added samples respectively. The CaSt2 particles were molten and recrystallized in base oil during preparation of the lubricant. Thus they have a different particle size than the original powder. At higher CaSt2 content the formed CaSt2 crystals were in smaller size due to fast nucleation and slow growth of crystals. The gelation of CaSt2 and base oil system is also another possibility affecting apparent size of particles. Fig. 5 - Settling of CaSt2 particles in base oilon the a. 1st day, b. 15th day after mixing Fig. 6 - The height of the boundary between clear base oil and CaSt2 particles settling in base oil Melting behavior of pure CaSt2.and CaSt2 in mineral oil CaSt2 powder melts at 120oC as determined by DSC and at 148oC by optical microscopy in a previous study [3]. In Fig. 7micrographs of the CaSt2 powders before and after melting are seen. Before melting CaSt2 appears as a white powder and on melting it is transformed into a transparent liquid. It was found that CaSt2 had a melting temperature of 142.8oC by optical microscopy in the present study. CaSt2 particles in base oil also showed a similar phase transition behavior as bulk CaSt2. They were dispersed as particles in base oil at room temperature. The particles kept their shape up to 113oC and they melted and mixed with mineral oil homogeneously at 128oC as seen in Fig. 8. Fig. 7 - Optical micrographs of CaSt2 powder at (a) 142.8 oC and (b) 156,6 oC Fig. 8 - Optical micrographs of CaSt2(1 %) dispersed in mineral oil at (a) 113oC (b) 128oC Friction and wear behavior of the lubricants The lubricants with CaSt2efficiently decreased the friction and wear between metal surfaces. The four ball test results are shown in Table 1, wear scar’s optical micrographs are seen in Fig. 9 and the change of friction coeficient during 1 hour test duration is seen in Fig. 10. Fig. 9 - Optical micrograhs of the wear scar diameters of the one of the fixed balls of four ball tests for (a) 1% CaSt2 (b) 2% CaSt2 containing lubricant The friction coefficient and wear scar diameter of base oil 0.099 and 1402 nm were reduced to 0.0730 and 627.61 nm respectively for the lubricant having 1 % CaSt2. For 2 % CaSt2 containing lubricant the friction coefficient and the wear scar diameter were 0.815 and 0.540 respectively. As the CaSt2 content increased better lubricating efficiency were observed. The four ball tests are done at 75oC. At this temperature CaSt2 is in solid form in base oil. However by the kinetic energy of the rotating ball over fixed balls the temperature of the oil should have been increased to melt the CaSt2 crystals in base oil and to cover the surface of the balls by a smooth lubricating layer. The solid CaSt2 particles similar to other nano particles can also fill the crevices and holes on the steel surface reducing the friction and wear. Fig. 10 - Change of the friction coefficient with time for a. 1% CaSt2 b. 2% CaSt2 containing lubricants Table 1 - Friction coefficient and wear scar diameter of base oil and lubricants with 1% and 2 % CaSt2 Property Base oil [2] Base oil with 1 % CaSt2 Base oil with 2 % CaSt2 Friction coefficient 0.099 0.0730 0.8150 Wear Scar Diameter, nm 1402 627.61 540.88 The effect of four ball tests on the color of the base oil The lubricants change their color due to oxidation, hydrolysis and thermal degradation during its use. Contaminants from the eroding surfaces also change the color of the oil. The solid colorants in the lubricating oil can be filtered and the filter surface color can be measured [9]. In the present study the color change of the lubricating oils during four ball tests were investigated by visible spectroscopy. The visible spectra of the lubricants shown in Figure 11 were taken using the base oil Fig.

11 - Visible spectra of the base oil 1.before four ball tests, 2. after four ball tests for 1% CaSt2 and 3. before four ball tests and 4. after four ball tests for2% CaSt2 as the reference. The base oil with 1% CaSt2 were lighter in color than the reference base oil as indicated by the negative absorbance values in Figure 11. CaSt2 adsorbed the coloring material initially existing in the base oil. After four ball test the base oil become dark yellow due to oxidation and crosslinking reactions in base oil. The base oil having 2% CaSt2 had higher absorbance values at all wavelengths and the absorbance was maximum at 420 nm. It also had a darker color after the test. Thus CaSt2 improves the lubricating efficiency of the base oil, but it does not increase the oxidative and thermal stability. Adding antioxidants to the system would help the thermal and oxidative stability which could be the subject of further investigations. Conclusion Calcium stearate powder prepared from sodium stearate and calcium chloride by precipitation from aqueous solutions and Light Neutral Base oil were mixed together to obtain lubricating oils. It was found that CaSt2 powder had a melting temperature of 142.8oC and in the base oil it melted above 128oC. From rate of settling of the particles in base oil the size of dispersed particles were found to be 1.88 µm and 0.11 µm respectively for lubricants having 1% and 2 % CaSt2. The friction coefficient (0.099) and wear scar diameter of base oil (1402 nm) were reduced to 0.0730 and 627.61 nm respectively for the lubricant having 1 % CaSt2.Lower wear scar diameter (540 nm) was obtained for lubricant with 2% CaSt2. Calcium stearate when added to base oil reduces the friction and wear of metal surfaces sliding on each other. It covers the cracks and groves of the metal surface with a smooth film. Thus it is an efficient lubricant additive. However CaSt2 did not increased oxidative and thermal stability of the base oil. Thus further studies for the antioxidant selection should be made.