The influence of size on the self-organization of magnetic particles: from nano to micro

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The magnetic microparticles used in many applications, such as immunomagnetic separation, are essentially ferromagnetic nanoparticles that are embedded within micron-sized polystyrene beads and their simulations require applications of particle tracking methods. The magnetic behavior of these particles differs from that of the corresponding bulk material. Their theoretical treatment also varies, since particle-particle interactions must be considered at the microscale. These interactions can alter how magnetic microparticles are prepared to perform biological and chemical functions that must be modeled. Microparticle suspensions are distinct from ferrofluids that are colloidal suspensions of magnetic nanoparticles. The nanoparticles in ferrofluids also have properties that are different from those of the bulk form of the same material. At room temperature the thermal Brownian energy of the individual particle magnetic domains in a ferrofluid supercedes the magnetocrystalline anisotropy energy. Since, for ferrous nanoparticles of small size, the blocking temperature is much lower than the room temperature, the nanoparticles exhibit superparamagnetic behavior. For this case, unlike the behavior of the bulk material, the particle magnetization does not exhibit hysteresis. The individual particle dipoles are randomly oriented due to thermal agitation in the absence of an externally applied magnetic field. Hence, the fluid does not exhibit any permanent magnetization. However, the bulk fluid begins to exhibit magnetic behavior when an imposed magnetic field induces the alignment of the thermally disoriented magnetic moments of these particles. Due to their larger size, the behavior of magnetic microparticles is quite different from that of the nanoparticles in a ferrofluid (described above). When an external magnetic field is applied, these microparticles align themselves along the field (unlike ferrofluids in which the nanoparticles agglomerate). Each magnetic microparticle acts as a magnetic dipole in a magnetic field and distorts the field around it considerably. Due to their strong dipole-dipole interactions, the microparticles are attracted toward one another and form chain-like assemblies in the direction of the magnetic field as illustrated in. Unlike nanoparticles, the motion of magnetic microparticles influences the fluid flow around them. While magnetic nanoparticles could also rotate when a magnetic field is rotated (depending upon whether their magnetic response is Néelian or Brownian), their rotation does not generally influence the surrounding fluid due their small size. Therefore, micro-particles must be treated formally as particles instead of as a second fluid as is typical in case of ferrofluids.