Qatar Univ, Sci, J. (1997), 17(1) : 55-60

A COMPARATIVE STUDY OF THE MECHANICAL PROPERTIES OF LOW DENSITY POLYETHYLENE (LDPE)

By

Z. Mohamed* M. E. Kassem and N. Salem***
Mechanical Engineering*, and Physics** Departments,
University of Qatar
P. O. Box 2713, Doha, Qatar

دراسة مقارنة للخواص الميكانيكية لمادة البولي ايثلين منخفض الكثافة

زهير محمد القاسم – محمد السيد قاسم – نبيل سالم
كلية الهندسة وكلية العلوم (جامعة قطر)

تمت دراسة الخواص الميكانيكية لعدة صور من مادة البولي ايثلين منخفض الكثافة من عينات شُكلت بطريقة البثق وأخرى بطريقة الضغط وقد أظهرت الدراسة إختلاف قي الخواص الميكانيكية لهذه العينات بالرغم من تشابه تركيبها الكيميائي وتشابه ظروفها السابقة. فسر هذا الإختلاف على أساس الوزن الجزيئي والمواد المضافة لهذه العينات وكذلك إختلاف معامل التدفق للمنصهر ، ولهذا يجب أخذ الإحتياطات اللازمة عند أختيار المادة الهندسية في التصميم وعند التشكيل واستخدام طريقة التصنيع المناسبة.

Keywords : Low density polyethylene, Method of process, Ductility, Modulus of elasticity :

ABSTRACT

Mechanical properties of engineering polymers which are the most important properties for design and construction purposes are diverse. This has been proved by investigation tensile properties of different grades of LDPE using tensile specimens processed by both injection moulding and compression moulding techniques. A considerable variation in these properties exists among the examined grades for similar chemical structures and similar previous history. The obtained results showed that mechanical properties for compressed samples are better then those obtained for the injected samples. This behaviour could be explained by the difference in the internal stress levels inside the material. Thus, caution must be exercised in selecting the material, its grade and its manufacturing method for a defined design.

INTRODUCTION

Many plastics are in competition with other engineering materials because they fulfil the needs which traditional materials cannot meet, either in terms of performance or economics. Such plastics posses high toughness and hardness and can withstand a wide range of temperatures and other environmental conditions (1). To mention but a few, the use of polyamide (PA) in small gears, the use of polytetrafluorethylene (PTFE) in high temperature applications and the use of polycarbonate (PC) in glazing. In addition, plastics are generally less dense than metals, so that their strength to weight ratios are highly favourable.

Despite these facts, plastics are not always as strong as metals and they are prone to dimensional changes under loads at high temperatures (2). Beside this, the mechanical behaviour of the plastics is quite different from that of other engineering materials for many reasons, all of which may substantially change the mechanical properties (3). For example, there are more than 70 basic structures (4) each of which is available in upto 100 different grades from different manufacturers which constrains the material selection process by design engineers. In addition, the plastics are usually modified by fillers (5), plasticizer (6), flame retardant (7) and impact modifiers (8), and a modification to increase one property may reduce the others(1).

On the other hand, most plastics can be easily fabricated into shaped parts by injection moulding or other processes, but the mechanical properties for these parts may vary considerably. Thus, it is intended in this work to investigate the effect of manufacturing method and slipping agent on the mechanical properties of five grades of Lotrene low density polyethylene (LDPE).

EXPERIMENTAL

The material investigated in the present work is Lotrene LDPE produced by QAPCO. Five different grades were used, namely: FB3003, FB5005, CD0230, FD0374 and FD0474. Some properties and various additives for the different grades, as supplied by the manufacturer are listed in Table 1. Tensile specimens of a dog-bone shape of the various grades were produced using injection moulding with the gauge length of 65 mm, width of 12.6 mm and thickness of 3.1 mm, The samples were produced using an injection temperature of 150°C, an injection pressure of 160 Kg/cm^2 and a die temperature of 25°C.

Another set of tensile specimens were produced of the same grades of the loterne LDPE using compression moulding with gauge length of 25 mm, width of 10 mm and thickness of 3 mm. The specimens were produced using a compression moulding machine at 30 Mpa and 165°C for 20 minutes

Tensile testing was carried out using Lloyd Instruments material testing machine linked to a remote microcomputer for data acquisition and analysis. The load was measured by a load cell 5 KN capacity, while the displacement was measured using an internal exteniometer. The speed of testing was 100 mm/min. Lloyd Data Analysis Package (DAP) was used to analyse the tensile properties from the load-extension diagrams. Detailed information about DAP are outlined elsewhere (9). Five samples were tested at the same conditions for each grade from each set.

RESULTS AND DISCUSSION

Typical stress-strain curves for injection moulded samples and for compression moulded samples are shown in Fig. (1-2) respectively. As can be seen in Fig. (1) for the injection samples, there is a continuous increase in stress with strain, up to fracture and the absence of yield points is visible. This type of deformation is usually termed as strain hardening (10). Comparing the curves in Fig. (1) indicate that FB grades have relatively higher ultimate tensile strength, lower ductility (strain at break), lower strain at maximum load and lower toughness (area under the stress strain curve) than FD grades, whereas CD0230 has an intermediate level of all tensile properties. The results may be not surprising, since the FB grades have relatively higher molecular weight as can be seen from their melt indices in Table 1, which is in accord with Ward (11) and Nielsen (12), they reported that as the molecular weight increases, so do the tensile strength. However, Gentle (13) reported that a higher molecular weight thermoplastic polymer will be tougher than a lower molecular weight polymer of the same chemical type which counteracts the present work as the FB grades showed the lowest values for toughness. This may reflect the presence of slipping agent in the FD grades examined as can be seen in Table 1.

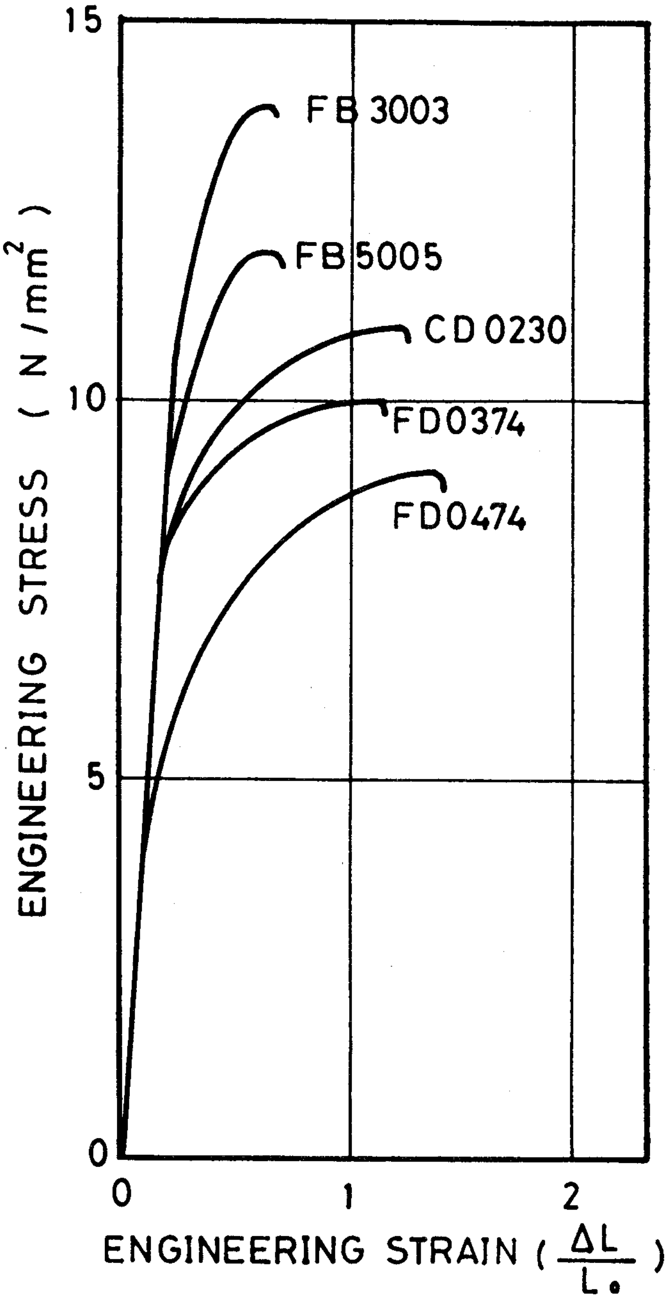

Fig. (1) Stress-Strain curves of the five grades LDPE for samples manufactured by injection moulding process.

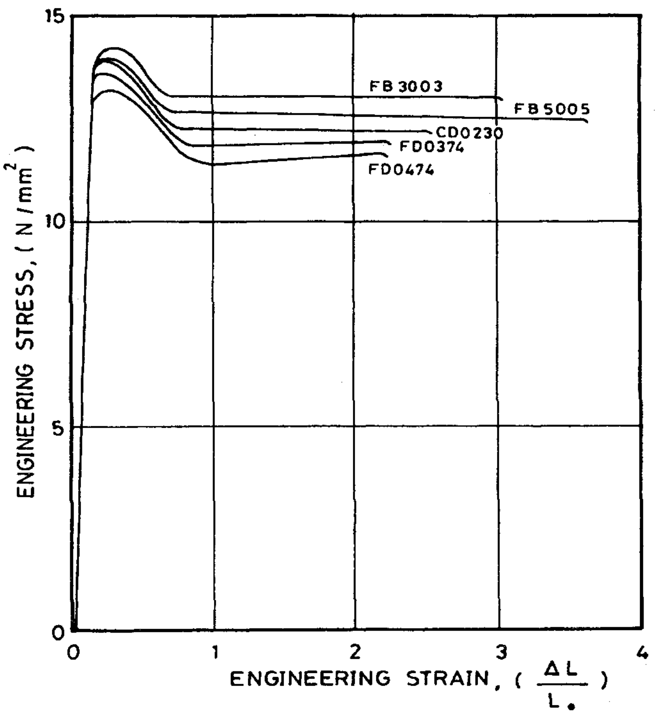

Fig. (2) Stress-strain curves of the five grades LDPE for samples manufactured by compression moulding process.

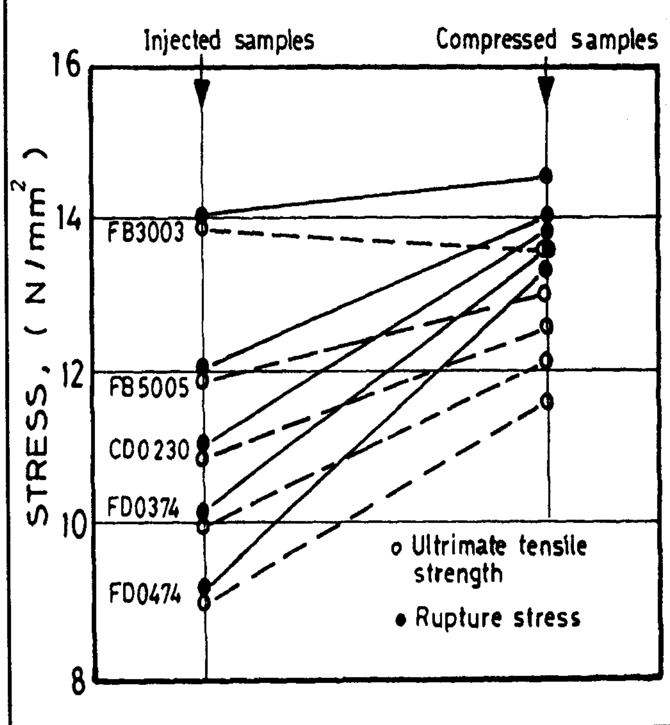

Fig. (3) Ultimate tensile strengths and rupture stresses of the different LDPE grades for injected and compressed samples.

Table 1: Technical Data for Lotrene LDPE

Polymer Properties	FB3003	FB5005	CD0230	FD0374	FD0374
Density (g/cm3)	0.919 - 0.921	0.919 - 0.921	0.920 - 0.922	0.920 - 0.922	0.920 - 0.922
Melt flow index (g/10 min)	0.3	0.6	0.3	0.7	4.7
Antioxidant (level) (ppm)	Nil	Nil	Nil	350 - 450	350 - 450
Slip agent (level) (ppm)	Nil	Nil	Nil	600 - 800	600 - 800
Antiblocking agent (level) (ppm)	Nil	Nil	Nil	1200	900 - 1100

The compressed samples (Fig. 2) showed completely another type of deformation as the stress-strain curves appeared with defined yield points followed by a near horizontal region. Such type of deformation is well known for soft and tough material (1). In this case again, FB grades showed higher ultimate tensile strengths and higher rupture stresses than FD grades and the CD0230 took the intermediate level, but the differences in strengths among the various grades examined were very small (<10%) compared with injected samples. On the other hand, it is of interest to note that FB grades have relatively higher toughness and higher ductilities than FD grades which has not been observed by the injected samples. Thus, the material behaviour may reflect the effect of molecular weight only, indicating that compression moulding demolishesthe effect of slipping agent observed in injected samples.

Ultimate tensile strength, rupture stress, ductility and toughness for both manufacturing methods (injection and compression) are shown in Figs. (3-5). It is clear from these figures that compressed samples have better mechanical properties than injected samples. This could be attributed to the fact that compressed samples have less internal stresses than injected samples (1). Pistole (13) concluded that uniform and minimum shrinkage of the plastic material can be expected when it is compression moulded. Gentle (1) confirmed this conclusion and he added that the tendency for shrinkage and consequently wrapping of the material is very high when it is injection moulded.

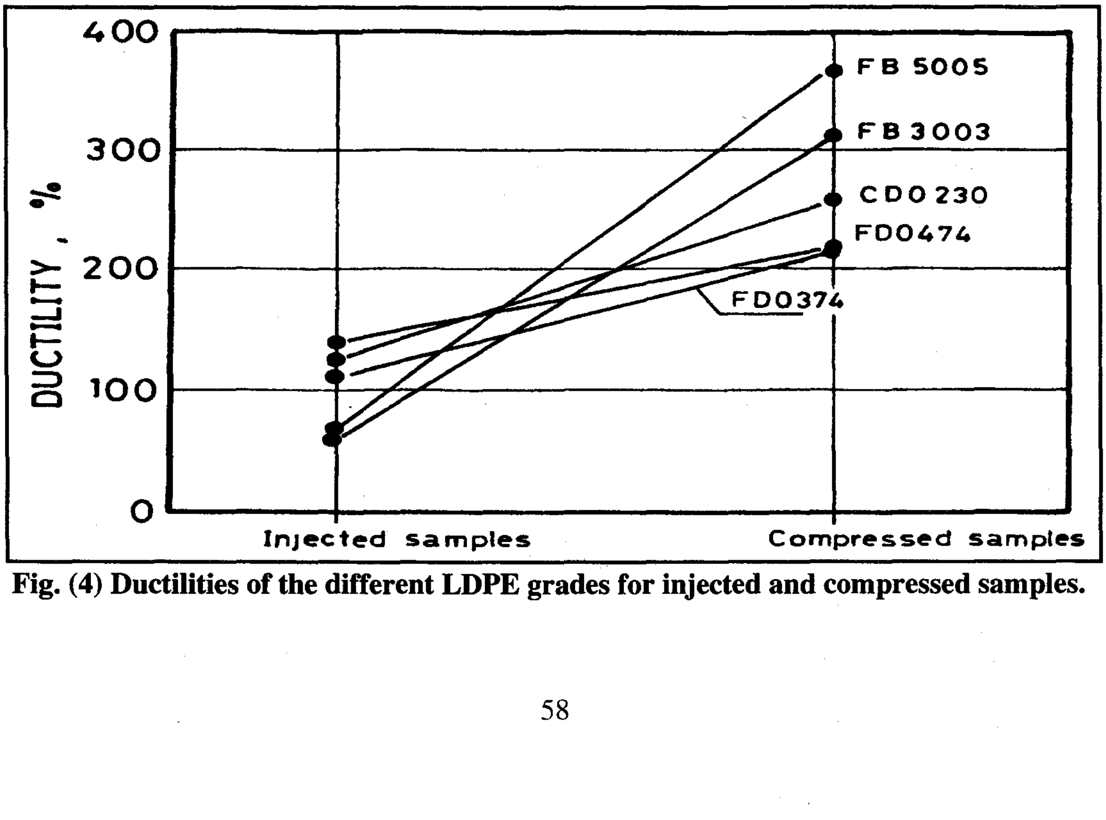

Fig. (4) Ductilities of the different LDPE grades for injected and compressed samples.

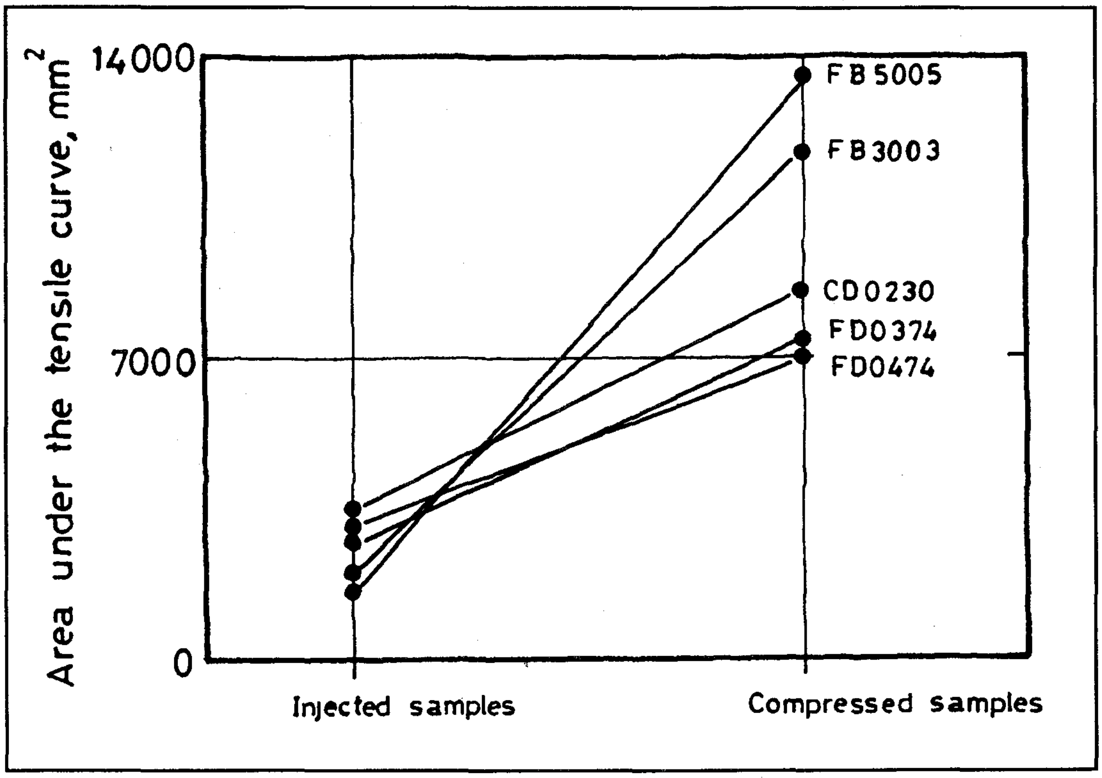

Fig. (5) Toughness of the different LDPE grades for injected and compressed samples.

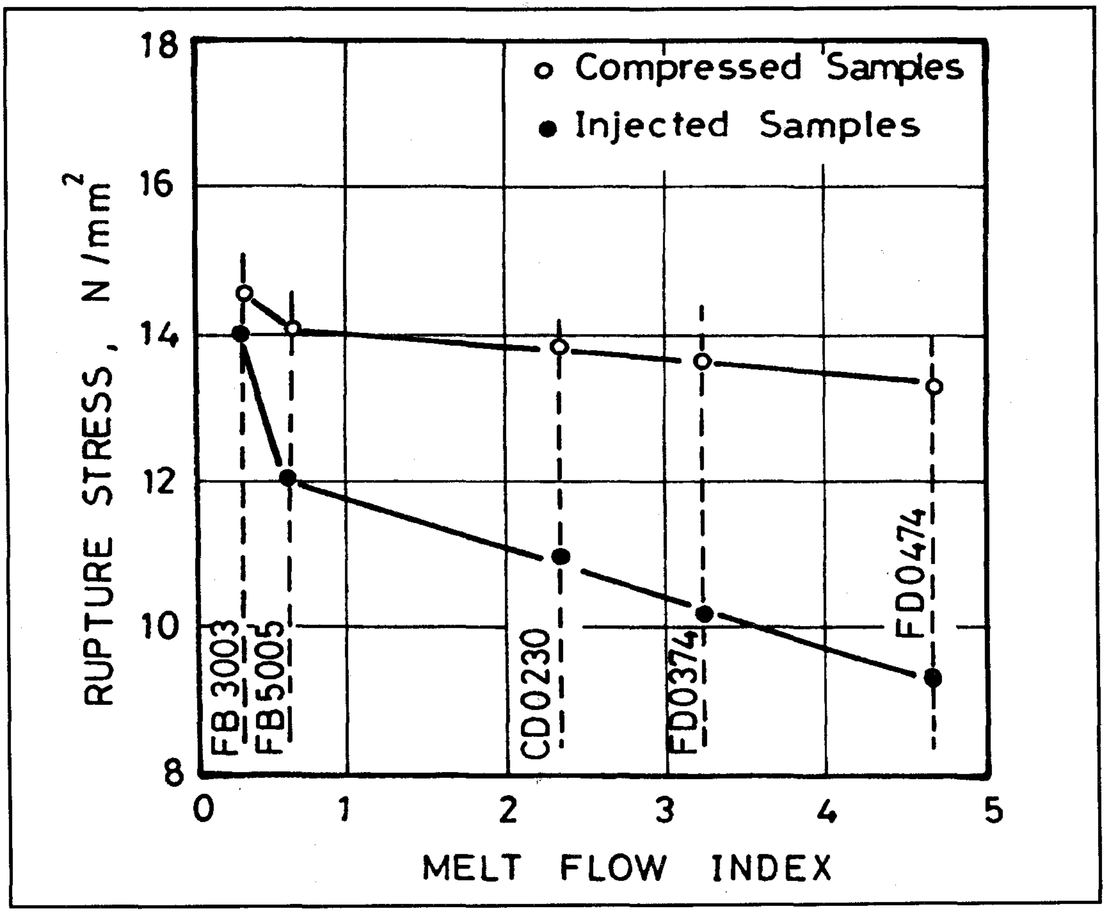

Fig. (6) Variation of rupture stress as a function of melt flow index for the injected and the compressed samples.

Fig. (6) show the variation of rupture stress as a function of melt flow index for the examined grades of LDPE. It is clear that the injected samples show a significant variation. This variation has been roughly diminished for compressed samples. This behaviour may be attributed to the lower massively and crystallinity (9) of the injected samples which have the higher internal stress levels.

However, caution must be taken by comparing the properties obtained from the different manufacturing methods, since each set of samples have been prepared under different processing conditions including the size of the samples.

CONCLUSION

1. Mechanical properties for different LDPE grades are diverse for the injected and compressed samples.
2. The compressed materials showed better mechanical properties due to the less internal stresses in the former group.
3. Adding slipping agent to the LDPE improved ductility and toughness in the injected material only.
4. The manufacturing process to be used for making an item of plastic should be selected when design and material being determined.
5. It is generally best for designing purposes to choose the properties region in which the response of the material is still elastic.

ACKNOWLEDGEMENT

The authors gratefully acknowledge support received from the Scientific and Applied Research Centre, University of Qatar in the funding of this research through project SARC03/6-1996. The assistance of Mr. Mohamed Said at the University of Qatar is gratefully appreciated.

REFERENCES

1. **Huang, J.C., 1988**, Mechanical properties, Engineering Plastics, Vol. 2, pp. 433-438, ASM International.
.2. **Felbeck, D.K. and Atkins, A.G., 1984**, Design consideration, Strength and Fracture of Engineering Solids, pp. 520-525, Prentice-Hall.
3. **La Mantia, F. B. , and Acierno , D. , 1985**. The rheological behaviour of HDPE HDPE/LDPE blends, plastic and rubber processing and applications, Vol. 5, p. 183 - 185.
4. **Deanin, R.D., 1982**, Polymer Structure, Properties and Applications, pp. 117-121, Cahners.
5. **Litman, A.M., and Fowler, N.E.,1971** Electrical properties, Engineering plastics, Vol. 2, pp. 460-468, ASM International.
6. **Askeland, D.R., 1996**, Polymers, The Science and Engineering of Materials, pp. 536-540, Chapman and Hall.
7. **Kienzie, S.Y., 1988**, Properties Modification by Use of Additives, Engineering plastics, Vol. 2, pp. 503-504, ASM International.
8. **Rifi, M.R. Ficker, H.K., and Walker, D.A., 1987**, Strain Hardening Polymers, Mod. Plastics, Vol. 64 (No. 2), pp. 62-68.
9. **Kandiel A. Y. , and Kassem , M. , 1991**. Physicomechanical properties and crystallinity of γ irradiated LDPE Thermochemica Acta, Vol. 191, pp. 333-340.
10. **Steidl, J. and Pelzbauer, Z., 1972**, J. Polym. Sci, 38C, pp. 345-350.
11. **Ward, I.M., 1983**, Mechanical properties of solid polymers, pp. 130-134, Second Edition, Wiley.
12. **Nielsen, L.E., 1974**, Mechanical properties of polymer composites, Vol. 2, p. 37-41, Dekker.
13. **Gentle, D.F., 1988**, Function and properties factors in process selection. Engineering Plastics, Vol. 2, pp. 279-288, ASM International.
14. **Pistole, R.D., 1980**, Compression Moulding and Stamping Engineering plastics, Vol. 2, pp. 324-333, ASM International.