PREDICTION IN CAE PROGRAMME WITH/WITHOUT REINFORCED PLASTIC PRODUCTION IN INJECTION MOLDING PROCESS

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Abstract: The aim of this paper is to get a prediction of some parametres about real time production of an injection molding process in computer media. A commercial CAE program was used for gathering datas that are required for a realtime injection process. And two different type of reinforced/unreinforced thermoplastic materials have been used in a plastic part model. Some parametres of injection molding process were compared with this programme. Obtained graphical results indicated an important prediction about real time injection process and provided to compare two different type of reinforced plastic.
In this study a standart plastic bolt was modelled in a CAD programme as a plastic model part. For reinforcement, short glass fiber was chosen from the CAE programme's material lab. And for thermoplastic materials were choosen pressure at injection location, filling time, cooling time, average fiber orientation and like some parametres were investigated in programme.
Keywords: Reinforced plastics, injection molding, CAE.

1. INTRODUCTION

1.1 Production method of thermoplastics

The most prevalent method for producing thermoplastic parts in large quantities is injection molding. This is a highly economical, efficient, and precise manufacturing method, which can be highly automated and produces almost no waste. It does, however, require expensive machinery and tooling. In addition, certain established geometric and other design considerations must be followed to consistently produce quality molded parts (Ticona, 2008).
In principle, injection moulding is a simple process. A thermoplastic, in the form of granules or powder, passes from a feed hopper into the barrel where it is heated so that it becomes soft. It is then forced through a nozzle into a relatively cold mould which is clamped tightly closed. When the plastic has had sufficient time to become solid the mould opens, the article is ejected and the cycle is repeated.

1.2 Principle of reinforcing thermoplastics

Despite of many advantages of plastics, engineers need plastics which have better phsical and mechanical properties. So that reinforced plastics (composite plastics) have emerged.Reinforced plastics have emerged as important materials because of their light-weight, high specific stiffness, high specific strength, excellent fatigue resistance and outstanding corrosion resistance compared to most common metallic alloys, such as steel and aluminium alloys.
One of the key factors which make plastics attractive for engineering applications is the possibility of property enhancement through fibre reinforcement. It was mentioned earlier that the stiffness and strength of plastics can be increased significantly by the addition of reinforcing filler.
The strength and stiffness of polymers are improved by adding fibres of glass, carbon, etc. (Crawford, 2007). In figure 1, below presented, both plastic material and short glass fiber were shown

Fig. 1. PP material and glassfiber

Glass in the form of fibres is relatively inexpensive and is the principal form of reinforcement used in plastics. The fibres are produced by drawing off continuous strands of glass from an orifice in the base of an electrically heated platinum crucible which contains the molten glass.
Fibre reinforced thermoplastics can be processed using most of the conventional thermoplastic processing methods. Extrusion, rotational moulding, blow moulding and thermoforming of short fibre

reinforced thermoplastics are all possible, but the most important commercial technique is injection moulding.

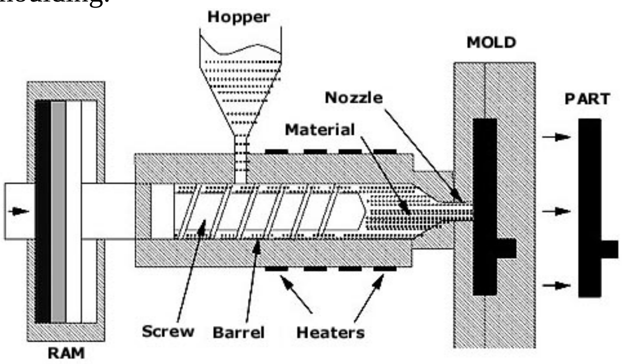

Fig. 2. Illustrating of injection moulding

In most respects this process is similar to the moulding of un-reinforced thermoplastics but there are a number of important differences. For example the melt viscosity of a reinforced plastic is generally higher than the unreinforced material. As a result the injection pressures need to be higher, by up to 80% in some cases. In addition the cycle times are generally lower because the greater stiffness of the material allows it to be ejected from the mould at a higher temperature than normal.

2. DESIGN PPOCESS, MODELLINDG and ANALYSIS

Initail design analysis could be maintained by two way. One of them is graphic analysis or geometric drawings and the other is engineering analysis. Geometric drawings depend on these procedures; dimensions and image manipulation, solid or surface modelling, static or dynamic mechanical simulation. Engineering analysis that would mentioned in this paper depend on structural integrity throught the finite element modelling.

There is also the combination of human creativity with computer technology that provides the design efficiency that has made CAD such a popular design tool. CAD is often thought of simply as computeraided drafting, and its use as an electronic drawing board is a powerhl tool in itself. The functions of a CAD system extend far beyond its ability to represent and manipulate graphics. Geometric modeling, enginccring analysis, simulation, and communication of the design information can also be performed using CAD (Rosato, 2003).

For many decades CAD has allowed the designer to bypass much of the manual drafting and analysis that was previously required, making the design process flow more smoothly and much more efficiently. It is helpful to understand the general product development process as a step-wise process (Kech & Vincent, 2008).

FEA (Finite Elemnent Analysis) procedure gives results that aproximately suitable for real time process parameters. Obtaing these results provide a predicion before real time production so wasting time importantly is reduced.

Although the thermo-mechanical requirements for the materials used increase the development cycles decrease. Numerical simulation, FEA, analysis can be a strong assistant when judging designs and reducing cost and time consuming experimental tests. The mechanical properties for short fibre reinforced thermoplastics are mainly dominated by fibre orientation which results from injection moulding process (Pontes et al., 2006).

3. A CASE FOR CAD AND FEA PROCESS

The program inputs are prepared in the preprocessor. Model geometry can be defined or imported from CAD software. Meshes are generated on a surface or solid model to form the elements, Element properties and material descriptions can be assigned to the model. Finally, the boundary conditions and loads are applied to the elements and their nodes. Certain checks must be completed before the analysis calculation. These include checking for duplication of nodes and elements and verifying the element connectivity of the surface elements so that the surface normals are all in the same direction.

In this study A standart plastic bolt was modelled and analyzied for injection molding process in commercial programme Moldflow. Two type of thermoplastic material were defined from the Moldflow Material Lab. PP (polypropylene) and PA (polyamid) and their glassfiber reinforced forms were used in analysis. Below There are some information about PP and PA thermoplastics. And plastic bolt that is modelled in a CAD progarmme .Plastic bolt model is saved as .STL format in CAD for progarmme for using it in Moldflow.

Polypropylene (PP); Polypropylene is an extremely versatile plastic and is available in many grades and also as a copolymer (ethylene/propylene). It has the lowest density of all thermoplastics (in the order of 900 kg/m3 and this combined with strength, stiffness and excellent fatigue and chemical resistance make it attractive in many situations. These include crates, small machine parts, car components (fans, fascia panels etc), chair shells, cabinets for TV, tool handles, etc. Its excellent fatigue resistance is utilised in the moulding of integral hinges (e.g. accelerator pedals and forceps/tweezers). Polypropylene is also available in fibre form (for ropes, carpet backing) and as a film (for packaging) (Kröner et al., 2009).

Polyamides (nylon); There are several different types of nylon (e.g. nylon 6, nylon 66, nylon 11) but as a family their characteristics of strength, stiffness and toughness have earned them a reputation as engineering plastics. Typical applications for nylon include small gears, bearings, bushes, sprockets, housings for power tools, terminal blocks and slide rollers. An important design consideration is that nylon absorbs moisture which can affect its properties and dimensional stability (Altenbach et al., 2003). Glass reinforcement reduces this problem and produces extremely strong, impact resistant material. Another major application of nylon is in fibres which are notoriously strong. The density of nylon is about 1100 kg/m^3 (Hyeyoung, 2009; Goh, 2004).

4. ANALYSIS RESULTS

Unreinforced PP/PA and Reinforced PP/PA (weight %20 and %40 glass fiber) are shown in below figures.

4.1 Filling analysis

Filling phase: Status: V=Velocity control, P = Pressure control, V/P = Velocity/pressure switch-over.

Table 1. Unreinforced PP (Left)

Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm^3/s	Status
0,82	5,22	0,03	0,00	0,47	V
1,63	10,21	0,03	0,00	0,47	V
2,41	15,10	0,04	0,00	0,47	V
3,21	20,04	0,04	0,00	0,47	V
4,04	25,18	0,04	0,00	0,47	V
4,80	29,91	0,04	0,00	0,47	V
5,61	34,86	0,05	0,00	0,47	V
6,40	39,70	0,09	0,00	0,47	V
7,20	44,54	0,12	0,00	0,47	V
8,00	49,39	0,16	0,00	0,47	V
8,80	54,22	0,20	0,00	0,47	V
9,60	59,04	0,25	0,00	0,47	V
10,41	63,90	0,30	0,01	0,47	V
11,20	68,64	0,35	0,01	0,47	V
12,02	73,52	0,40	0,01	0,47	V
12,80	78,19	0,45	0,01	0,47	V
13,65	83,25	0,50	0,01	0,47	V
14,40	87,74	0,55	0,01	0,47	V
15,21	92,54	0,61	0,01	0,47	V
16,00	97,26	0,67	0,01	0,47	V
16,28	98,95	0,69	0,01	0,47	V/P
16,30	99,01	0,55	0,01	0,25	P
16,56	99,93	0,55	0,01	0,26	P
16,56	100,00	0,55	0,01	0,26	Filled

Table 2. Unreinforced PA (right)

Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm^3/s	Status
0,52	5,20	0,00	0,00	0,74	V
1,03	10,11	0,00	0,00	0,74	V
1,53	14,98	0,00	0,00	0,74	V
2,05	19,99	0,00	0,00	0,74	V
2,57	24,96	0,01	0,00	0,74	V
3,07	29,83	0,01	0,00	0,74	V
3,57	34,63	0,01	0,00	0,74	V
4,08	39,51	0,01	0,00	0,74	V
4,59	44,32	0,02	0,00	0,74	V
5,10	49,15	0,02	0,00	0,74	V
5,63	54,11	0,03	0,00	0,74	V
6,12	58,69	0,04	0,00	0,74	V
6,66	63,70	0,04	0,00	0,74	V
7,15	68,27	0,05	0,00	0,74	V
7,65	72,97	0,06	0,00	0,74	V
8,18	77,84	0,08	0,00	0,74	V
8,67	82,40	0,09	0,00	0,74	V
9,19	87,18	0,11	0,00	0,74	V
9,70	91,90	0,12	0,00	0,74	V
10,20	96,54	0,14	0,00	0,74	V
10,47	99,00	0,15	0,00	0,74	V/P
10,48	99,10	0,12	0,00	0,59	P
10,59	99,92	0,12	0,00	0,55	P
10,60	100,00	0,12	0,00	0,55	Filled

Table 3. % 20 Glass reinforced Pp (left)

Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm^3/s	Status
0,92	5,19	0,01	0,00	0,42	V
1,81	10,07	0,01	0,00	0,42	V
2,70	14,95	0,01	0,00	0,42	V
3,64	20,06	0,02	0,00	0,42	V
4,52	24,81	0,02	0,00	0,42	V
5,41	29,66	0,02	0,00	0,42	V
6,32	34,48	0,02	0,00	0,42	V
7,20	39,17	0,02	0,00	0,42	V
8,11	43,93	0,05	0,00	0,42	V
9,01	48,64	0,07	0,00	0,42	V
9,91	53,31	0,09	0,00	0,42	V
10,80	57,99	0,12	0,00	0,42	V
11,72	62,73	0,14	0,00	0,42	V
12,60	67,32	0,17	0,00	0,42	V
13,50	71,98	0,21	0,00	0,42	V
14,41	76,65	0,24	0,00	0,42	V
15,31	81,28	0,28	0,01	0,42	V
16,21	85,93	0,32	0,01	0,42	V
17,10	90,52	0,36	0,01	0,42	V
18,00	95,14	0,40	0,01	0,42	V
18,75	99,00	0,44	0,01	0,42	V/P
18,77	99,07	0,35	0,01	0,31	P
18,90	99,57	0,35	0,01	0,31	P
18,99	99,91	0,35	0,01	0,29	P
19,00	100,00	0,35	0,01	0,29	Filled

Table 4. % 20 Glass reinforced PA (right)

Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm^3/s	Status
0,90	5,20	0,00	0,00	0,39	V
1,77	10,01	0,00	0,00	0,39	V
2,54	14,55	0,00	0,00	0,39	V
3,48	19,76	0,00	0,00	0,39	V
4,34	24,11	0,01	0,00	0,39	V
5,23	29,36	0,01	0,00	0,39	V
6,19	34,28	0,01	0,00	0,39	V
7,13	39,03	0,02	0,00	0,39	V
8,01	43,63	0,06	0,00	0,39	V
9,00	48,34	0,08	0,00	0,39	V
9,51	53,01	0,09	0,00	0,39	V
10,30	57,59	0,13	0,00	0,39	V
11,22	62,43	0,14	0,00	0,39	V
12,10	67,02	0,17	0,00	0,39	V
13,20	71,68	0,21	0,00	0,39	V
14,11	76,35	0,25	0,00	0,39	V
15,12	81,08	0,29	0,01	0,39	V
16,01	85,63	0,33	0,01	0,39	V
17,00	90,22	0,37	0,01	0,39	V
17,57	94,89	0,41	0,01	0,39	V
18,43	98,50	0,46	0,01	0,39	V/P
18,39	99,01	0,37	0,01	0,27	P
18,51	99,17	0,35	0,01	0,27	P
18,49	99,51	0,34	0,01	0,25	P
19,00	100,00	0,34	0,01	0,25	Filled

Table 5. % 40 Glass reinforced Pp (left)

Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm^3/s)	Status
0,77	5,19	0,00	0,00	0,50	V
1,51	10,07	0,00	0,00	0,50	V
2,25	14,96	0,00	0,00	0,50	V
3,03	20,06	0,00	0,00	0,50	V
3,76	24,84	0,00	0,00	0,50	V
4,50	29,73	0,00	0,00	0,50	V
5,28	34,76	0,00	0,00	0,50	V
6,00	39,37	0,00	0,00	0,50	V
6,75	44,15	0,00	0,00	0,50	V
7,51	48,93	0,00	0,00	0,50	V
8,26	53,67	0,00	0,00	0,50	V
9,01	58,36	0,01	0,00	0,50	V
9,75	63,04	0,01	0,00	0,50	V
10,55	68,03	0,01	0,00	0,50	V
11,25	72,43	0,01	0,00	0,50	V
12,00	77,11	0,01	0,00	0,50	V
12,77	81,88	0,01	0,01	0,50	V
13,53	86,61	0,01	0,01	0,50	V
14,25	91,15	0,02	0,01	0,50	V
15,01	95,86	0,02	0,01	0,50	V
15,51	98,94	0,02	0,01	0,50	V/P
15,52	99,00	0,02	0,01	0,28	P
15,75	99,92	0,02	0,01	0,31	P
15,75	100,00	0,02	0,01	0,31	Filled

Table 6. %40 Glass reinforced PA (right)

Time (s)	Volume (%)	Pressure (MPa)	Clamp force (tonne)	Flow rate (cm^3/s)	Status
0,77	5,07	0,03	0,00	0,71	V
1,51	10,08	0,04	0,00	0,71	V
2,25	15,16	0,04	0,00	0,71	V
3,03	20,08	0,04	0,00	0,71	V
3,76	25,06	0,04	0,00	0,71	V
4,50	29,91	0,04	0,00	0,71	V
5,28	34,92	0,05	0,00	0,71	V
6,00	39,69	0,10	0,00	0,71	V
6,75	44,59	0,13	0,00	0,71	V
7,51	49,45	0,18	0,00	0,71	V
8,26	54,28	0,22	0,00	0,71	V
9,01	59,16	0,28	0,01	0,71	V
9,75	63,99	0,35	0,01	0,71	V
10,55	69,02	0,42	0,01	0,71	V
11,25	73,63	0,50	0,01	0,71	V
12,00	78,44	0,59	0,01	0,71	V
12,77	83,32	0,69	0,02	0,71	V
13,53	88,06	0,79	0,02	0,71	V
14,25	92,88	0,90	0,02	0,71	V
15,01	97,67	1,02	0,02	0,71	V
15,51	99,00	1,06	0,02	0,71	V/P
15,52	99,11	0,85	0,02	0,54	P
15,75	99,94	0,85	0,02	0,52	P
15,75	100,00	0,85	0,02	0,52	Filled

4.2 Fill time for Unreinforced PP and PA

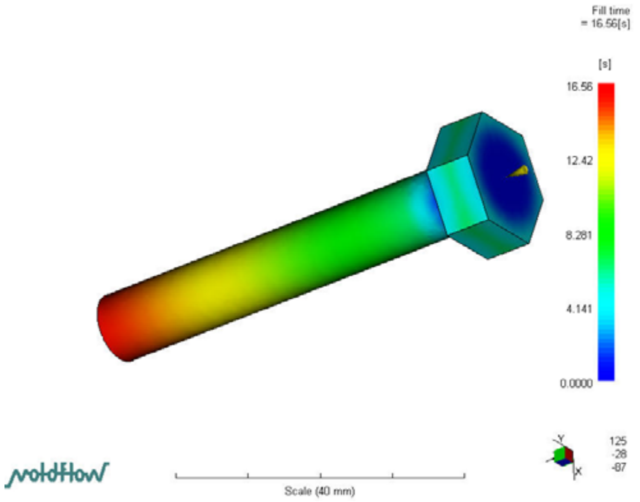

Fig. 3. PP fill time :16,56 s

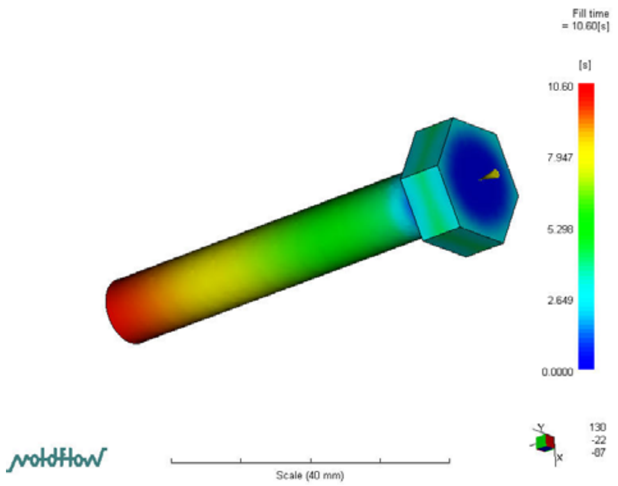

Fig. 4. PA fill time: 10,60 s

4.3 Fill time for %20 and %40 glassfiber reinforced PP and PA

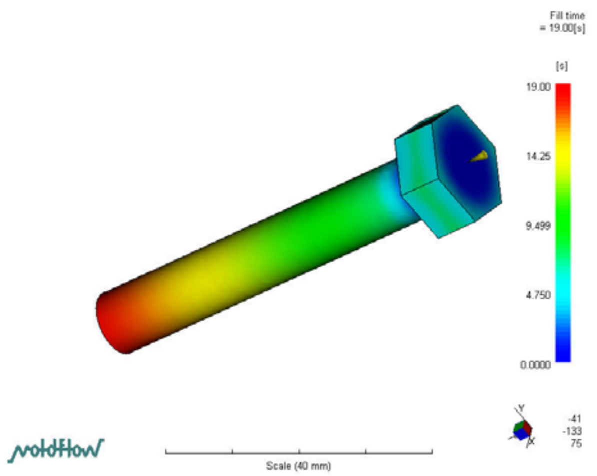

Fig. 5. %20 glassfiber PP filltime:19,00 s

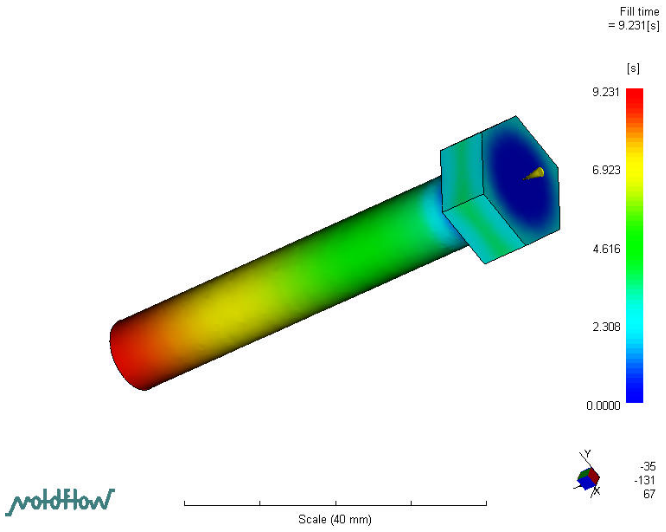

Fig. 6. %20 glassfiber PA filltime: 9,231 s

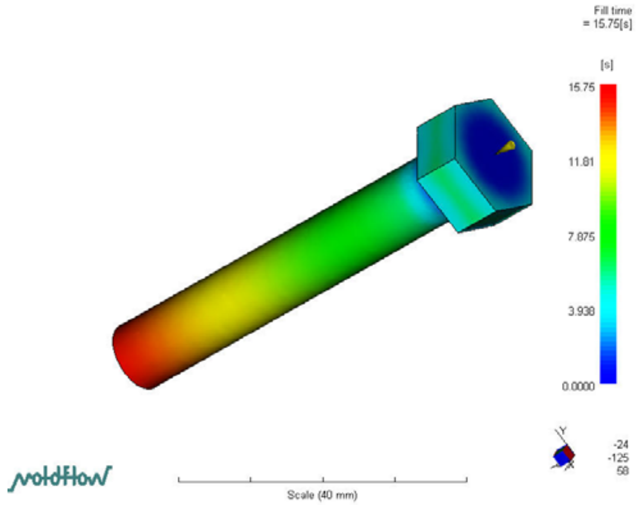

Fig. 7. %40 glasfiber PP filltime:15,75 s

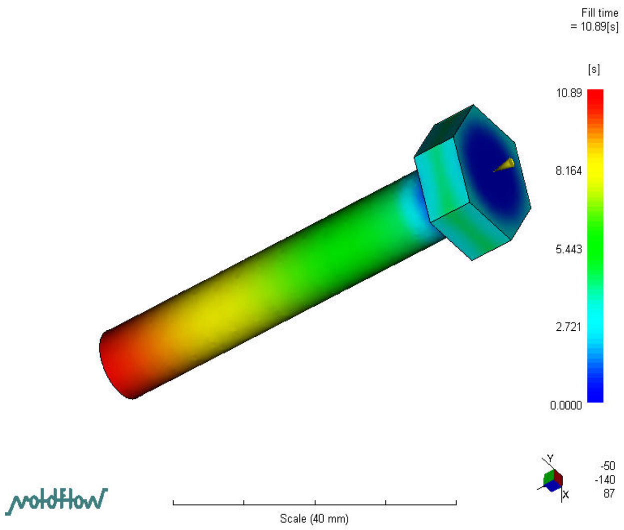

Fig. 8. %40 glassfiber PA filltime: 10,89 s

4.4 Average fiber orientation %20 and %40 glassfiber reinforced PP and PA

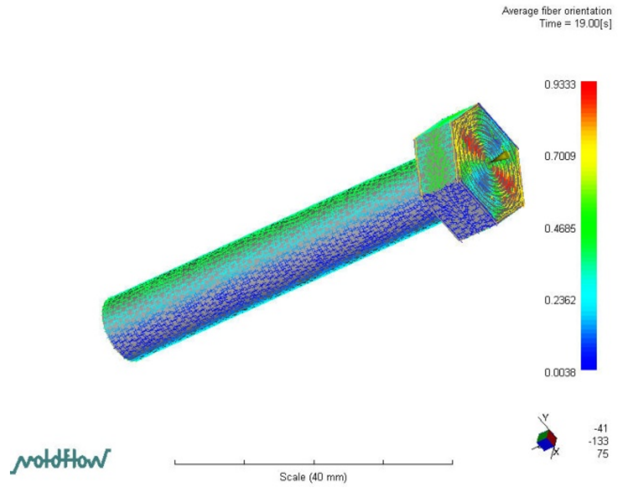

Fig.9. PP avg. Fiber orientation is 0.9333 in 19 s

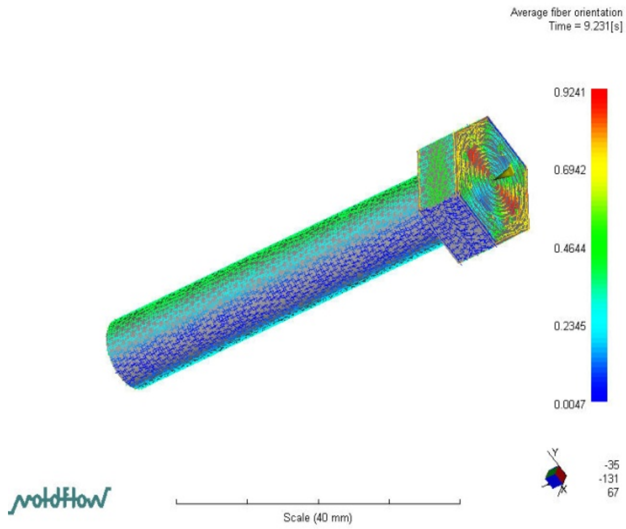

Fig. 10. PA avg. fiber orientation is 0,9241 in 9,231 s

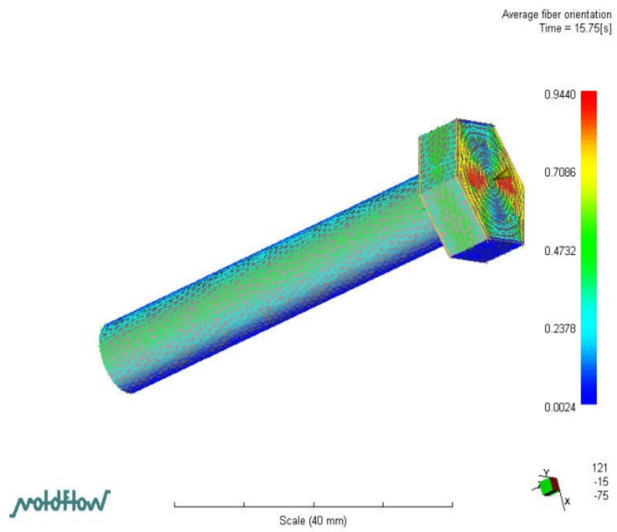

Fig. 11. Avg. fiber orientation is 0.9440 in 15,75 s

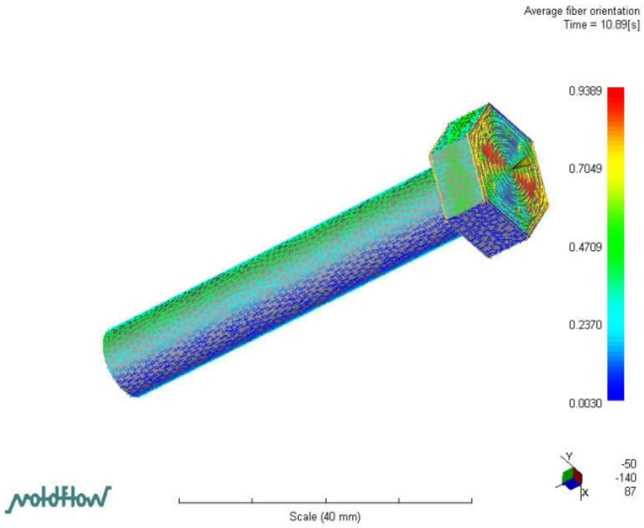

Fig.12. PA avg. fiber orientation is 0.9389 in 10,89 s

4.5 Filling phase results summary for the part: unreinforced PP and PA

Unreinforced PP: Bulk temperature - maximum (at 16.295s)=204.8280 ^{0}C, Bulk temperature - minimum (at 16.531s)=172.3300 ^{0}C,
Unreinforced PA: Bulk temperature - maximum (at 0.524s)= 264.8880 ^{0}C, Bulk temperature - minimum (at 10.594s)=240.0730 ^{0}C

4.6 Filling phase results summary for the part: %20 glassfiber reinforced PP and PA

Bulk temperature - maximum (at 0.921s)= 215.8110 ^{0}C, Bulk temperature - minimum (at 18.995s)=176.7400 ^{0}C,
Bulk temperature - maximum (at 0.457s)= 264.8940^{0}C, Bulk temperature - minimum (at 9.229s)= 241.0890 ^{0}C.

4.7 Filling phase results summary for the part: %40 glassfiber reinforced PA

%40 GFR PP: Bulk temperature - maximum (at 15.517s)=217.8060 ^{0}C, Bulk temperature – minimum (at 15.729s)=182.3200^{0}C,
%40 GFR PA: Bulk temperature - maximum (at 0.532s)=259.8910 ^{0}C, Bulk temperature - minimum (at 10.868s)=236.4270 ^{0}C.

5. CONCLUSIONS

In this study commercial CAD and CAE programme were used for determining parameters that is proper for real time production of injection molding. Some process properties of two different type of unreinforced/reinforced tehrmoplastic PP and PA was compared. In analysis results more information was given that wolud be used for prediction of real time injection molding process. From filling analysis necessary datas that are clamp force, filling time, pressure, bulk temperature etc. were obtained. These datas can use for real time process. And informations about fiber orientation give an aproach about behaviour of fibers in matrix material. If this standart plastic bolt was produced in injection molding process, analysis results give an opinion to engineers which material is proper and effective for real time production. And about production of reinforced plastics, what sort of varience occurs in reinforcement increment in matrix can be observed by the programme.

6. ACKNOWLEDGEMENTS

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